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DEPARTMENT OF ECONOMIC AND REGIONAL DEVELOPMENT

MASTER'S DEGREE PROGRAM IN APPLIED ECONOMICS AND REGIONAL DEVELOPMENT

DIRECTION: APPLIED ECONOMICS AND MANAGMENT

MASTER THESIS

# Environmental impacts and nutrient density of four diet plans: USDA sample menus, Modern Greek, Vegan, and Whole-Food Plant-Based

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*To my amazing family, who have been a constant source of support and motivation throughout my studies.*

*Abbreviations*

ALA: alpha linolenic acid

BMI: Body Mass Index

CAD: coronary artery disease

CVD: cardiovascular disease

DGA: Dietary Guidelines for Americans

DHA: docosahexaenoic acid

DRI: Dietary Reference Intakes

DV: Daily Value

EAR: Estimated Average Requirement

EFSA: European Food Safety Authority

EPA: eicosapentaenoic acid

FBDG: Food-Based Dietary Guidelines

FDC: Food Data Central

FNDDS: Food and Nutrient Database for Dietary Studies

FQS: Food Quality Score

HEI: Healthy Eating Index

IDF: Index of Debt to the Future

MAFCL: Methods and Application of Food Composition Laboratory

MDP: Mediterranean Dietary Pattern

MDS: Mediterranean Diet Score

MRSA: Methicillin-resistant Staphylococcus aureusk

MRV: Maximum Recommended Values

NCDs: Non-Communicable Diseases

NO: Nitric Oxide

NP: Nutrient Profiling

NRD: Nutrient Rich Diet

NRF: Nutrient Rich Foods

PCRM: Physicians Committee for Responsible Medicine

PRI: Population Reference Intake

RDA: Recommended Dietary Allowance

RNI: Recommended Nutrient Intake

SCFA: short-chain fatty acid

SFA: Saturated Fatty Acids

SDGs: Sustainable Development Goals

USDA: United States Department of Agriculture

WFPB: Whole-Food Plant-Based

*Acknowledgements*

I would like to express my gratitude to the following people, who each in their own way made this research possible.

First of all, I would like to thank my supervisor, Dr. Anastasia Psiridis, who provided support with her scientific knowledge and experience, as well as giving important advice and guidance and undivided support throughout the whole project.

I would also like to express my sincere appreciation to Maria-Elisabeth Bora, who provided me with a wealth of information and data, which she had used in her thesis, published in 2021, as well as support regarding the writing of this thesis.

Finally, I would like to express my deepest gratitude to my beloved family and friends for their support throughout my studies.

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## Abstract

The issue of nutrition has been the subject of extensive study from a public health, economic and, in recent decades, environmental perspective. The consumption of nutrient-dense foods, i.e. those that combine high intakes of important nutrients with relatively few calories, has been consistently linked to avoidance and better management of certain diseases and generally better health outcomes. The link between dietary choices and patterns and health is largely acknowledged, and the relationship between the former and environmental issues such as greenhouse gas emissions, biodiversity loss, and the depletion of natural resources has also become an issue of concern.

In a previous master's thesis, the nutritional value of four different types of diet (USDA, Greek, Vegan and WFPB - each represented by weekly menus) – was compared using the NRD index which includes 2 nutrients to encourage (Vitamin C and fiber) and one nutrient to limit (saturated fat). The choice of the two positive nutrients was based on their high correlation with other nutrients to encourage. In this thesis we enrich the index with 5 other nutrients to encourage (Vitamin A, Iron, Potassium, Magnesium and Zinc) in order to explore whether and to what extent the results would change in terms of nutrient density of the four diets as well as to re-compare them. We conclude that after enriching the index with 5 additional nutrients, the WFPB remains the most nutritionally adequate diet

In addition, we examine and compare the water footprint of each of the four diets. We calculate the water footprint of each of the 7 weekly menus (49 daily menus in total) based on WFN data and other sources.

We find that, after the addition of 5 more nutrients to the index, the WFPB menus are still the healthiest ones, with a total NRD index score of 155.98, followed by the Vegan menus with a score of 108,57. The USDA menus had a score of 42.58 and the Greek had the lowest score of 40.45.

Furthermore, in terms of the water footprint of each diet, the Vegan diet has the lowest water footprint scoring with 98,535.06, followed by the WFPB diet with a score of 124,181.32, and then the Greek and USDA diets with scores of 274,575.02 and 363,502,64, respectively.

Therefore, the use of simpler indices can be equally informative for the assessment the nutrient density of a diet provided that nutrients used have a high correlation with nutrients omitted. Furthermore, we find that WFPB may be the most sustainable option in terms of water consumption, as it has the lowest water footprint of all four diets we examined.

*Keywords:* Nutrient density, nutrient profiling, water footprint of diets, Whole Food Diets, Vegan Diets

## Περίληψη

Το ζήτημα της διατροφής έχει αποτελέσει αντικείμενο εκτεταμένης μελέτης από άποψη δημόσιας υγείας, οικονομικής και, τις τελευταίες δεκαετίες, περιβαλλοντικής σκοπιάς. Η κατανάλωση τροφίμων με υψηλή περιεκτικότητα σε θρεπτικά συστατικά, δηλαδή εκείνων που συνδυάζουν μεγάλη πρόσληψη σημαντικών θρεπτικών συστατικών με σχετικά λίγες θερμίδες, έχει συνδεθεί σταθερά με την αποφυγή και την καλύτερη αντιμετώπιση ορισμένων ασθενειών και γενικά με καλύτερα αποτελέσματα στην υγεία. Η σχέση μεταξύ των διατροφικών επιλογών και μοτίβων και της υγείας είναι σε μεγάλο βαθμό αποδεκτή, ενώ η σχέση μεταξύ των πρώτων και περιβαλλοντικών ζητημάτων, όπως οι εκπομπές αερίων του θερμοκηπίου, η απώλεια της βιοποικιλότητας και η εξάντληση των φυσικών πόρων, έχει επίσης καταστεί αντικείμενο προβληματισμού.

Σε μια προηγούμενη μεταπτυχιακή διατριβή η διατροφική αξία τεσσάρων διαφορετικών τύπων διατροφής (USDA, Ελληνική, Vegan και WFPB - κάθε μία από τις οποίες αντιπροσωπεύεται από εβδομαδιαία μενού) - συγκρίθηκε με τη χρήση του δείκτη NRD, ο οποίος περιλαμβάνει 2 θρεπτικά συστατικά προς ενθάρρυνση (βιταμίνη C και φυτικές ίνες) και ένα θρεπτικό συστατικό προς περιορισμό (κορεσμένα λιπαρά). Η επιλογή των δύο θετικών θρεπτικών συστατικών βασίστηκε στην υψηλή συσχέτισή τους με άλλα θρεπτικά συστατικά προς ενθάρρυνση. Στην παρούσα διατριβή εμπλουτίσαμε τον δείκτη με άλλα 5 θρεπτικά συστατικά προς ενθάρρυνση (βιταμίνη A, σίδηρο, κάλιο, μαγνήσιο και ψευδάργυρο) προκειμένου να διερευνήσουμε αν και κατά πόσο θα άλλαζαν τα αποτελέσματα όσον αφορά τη θρεπτική πυκνότητα των τεσσάρων διαιτών καθώς και να τα συγκρίνουμε εκ νέου. Καταλήγουμε στο συμπέρασμα ότι μετά τον εμπλουτισμό του δείκτη με 5 επιπλέον θρεπτικά συστατικά, η WFPB παραμένει η πιο διατροφικά επαρκής διατροφή.

Επιπλέον, εξετάζουμε και συγκρίνουμε το υδατικό αποτύπωμα καθεμιάς από τις τέσσερις διατροφές. Υπολογίζουμε το υδατικό αποτύπωμα καθενός από τα 7 εβδομαδιαία μενού (49 ημερήσια μενού συνολικά) με βάση τα δεδομένα του WFN και άλλων πηγών.

Διαπιστώνουμε ότι, μετά την προσθήκη 5 ακόμη θρεπτικών συστατικών στον δείκτη, τα μενού της WFPB διατροφής εξακολουθούν να είναι τα πιο υγιεινά, με συνολική βαθμολογία δείκτη NRD , ακολουθούμενα από τα Vegan μενού με βαθμολογία 108.57. Το μενού της USDA διατροφής είχε βαθμολογία 42.58 και τα μενού της ελληνικής διατροφής είχαν τη χαμηλότερη βαθμολογία 40.45.

Επιπλέον, όσον αφορά το υδατικό αποτύπωμα κάθε διατροφής, η Vegan έχει το χαμηλότερο υδατικό αποτύπωμα, σημειώνοντας βαθμολογία 98,535.06, ακολουθούμενη από την WFPB με βαθμολογία 124,181.32 και στη συνέχεια από την ελληνική και USDA με βαθμολογίες 274,575.02 και 363,502.64 αντίστοιχα.

Επομένως, η χρήση απλούστερων δεικτών μπορεί να είναι εξίσου κατατοπιστική για την αξιολόγηση της θρεπτικής πυκνότητας μιας δίαιτας, υπό την προϋπόθεση ότι τα θρεπτικά συστατικά που χρησιμοποιούνται έχουν υψηλή συσχέτιση με τα θρεπτικά συστατικά που παραλείπονται. Επιπλέον, διαπιστώνουμε ότι η WFPB μπορεί να είναι η πιο βιώσιμη επιλογή όσον αφορά την κατανάλωση νερού, καθώς έχει το χαμηλότερο υδατικό αποτύπωμα και από τις τέσσερις δίαιτες που εξετάσαμε.



*Λέξεις-κλειδιά:* Θρεπτική πυκνότητα, θρεπτικό προφίλ, υδατικό αποτύπωμα των διατροφών, Whole Food διατροφή, Χορτοφαγική διατροφή

## Introduction – Review of literature

Dietary patterns are closely linked to health and well-being. Poor diet quality has been shown to be one of the main factors associated with ill-health, disability, or early death, as it contributes to the development of a variety of chronic diseases such as cardiovascular disease, diabetes, respiratory diseases, and cancer. The consumption of large quantities of red and processed meat contributes to health burden. In addition, energy intake in excess of one's needs leads to an increased Body Mass Index, which is also an important factor leading to adverse health effects (Murray et al., 2020).

The global burden of non-communicable diseases has increased in recent decades to such an extent that it requires policies and interventions to reduce it. Indicative of this is the fact that cardiovascular disease is increasing in non-high-income countries of the world, as well as the fact that it is occurring at younger ages than in the past. The dietary factor is a key determinant of the global burden of disease, as it is linked to dietary patterns where certain food groups are either underconsumed or overconsumed (Roth et al., 2020).

The scientific debate on the presence of meat and animal products in the human diet in order to achieve health is ongoing. There are arguments both for and against the presence of such foods in the diet. A portion of researchers argue that a plant-based diet can lead to serious nutrient deficiencies, which in turn cause serious health problems such as hyperhomocysteinemia and atherogenesis. This is because the sound planning of a vegetarian diet and the supplements that are necessary when adopted are often omitted (Ingenbleek & McCully, 2012). Other researchers have cited such evidence, coupled with the biological adaptation of humans to meat eating, to question the nutritional robustness of a plant based diet, and by extension, many dietary guidelines that suggest a significant reduction in meat consumption (Leroy & Cofnas, 2020).

Indeed, deficiencies in certain vitamins and minerals are often observed in people following a vegan and WFPB diet. Various studies have shown the benefits of a vegan and WFPB diet, such as the reduction of total and LDL cholesterol, as well as the protection it offers against some forms of cancer, diabetes, obesity and cardiovascular disease, among others. These benefits result from the reduced intake of saturated fat and sodium brought about by abstaining from animal products and processed foods and replacing them with fruits, vegetables, nuts and legumes. At the same time, the same studies point out that deficiencies in Vitamin D and B12, as well as iodine are the most common among vegans. Nevertheless, the appropriate food combinations included in the vegan diet can largely cover the intake of the necessary micronutrients and macronutrients. For example, vegans receive from their diet the same amount of iron, as non-vegans, but iron from plants is not as easily absorbed as iron from animal sources. This can be alleviated by eating ascorbic acid, found in foods such as kiwi and citrus fruits. (Sakkas et el., 2020) Therefore, careful planning of a plant based diet, the key factor in order to reap the maximum benefits offered by this dietary choice and to minimize the side effects that are likely to be caused by poor planning and failure to take supplements if needed.

International organizations, governmental institutions and scientific organizations aiming to promote human health focus on nutrition as a key factor in achieving it. In particular, the World Health Organization, which is part of the United Nations, has described healthy nutrition in detail. Consumption of at least five servings of fruits and vegetables, combined with legumes, nuts and whole grains is strongly encouraged. On the other hand, sugar intake should ideally be limited to 5% and not exceeding 10% of total energy intake. Fat intake should be less than 30% of daily calories. WHO distinguishes between unsaturated, saturated and trans fats and clearly states that trans fats - whether industrially produced and found in processed, packaged foods or ruminant fats found in meat and dairy products from ruminants such as goats, sheep and cows - have no place in a healthy diet. In addition, consumption of unsaturated fats found in fish, nuts, avocados and olive oil is preferred, while the intake of saturated fats found mainly in meat, butter, cheese and certain plant oils is highly discouraged. As part of a healthy diet, the WHO also recommends that daily intake of iodized salt should be less than 5g or one teaspoon.

The above description of healthy diet applies to the adult population of a healthy body weight and with an intake of approximately 2,000 calories per day. WHO however emphasizes that healthy eating practices and habits should be introduced at an early age. Regarding infants and children, healthy diet recommendations remain mostly the same as to those for adults. Moreover, the significance of exclusive breastfeeding until for the first six months of life and continuation of it complemented with nutritionally rich foods at least until the age of two years, is repeatedly highlighted in the context of optimal physical and cognitive development, as well as reduction various health risks later in life (WHO, 2018).

The Dietary Guidelines for Americans, which are updated every five years by the U.S. Department of Agriculture (USDA) and the Department of Health and Human Services, are in the same spirit as the WHO, recommending the consumption of fruits, vegetables and grains, low-fat dairy and protein foods of either animal or plant origin, as well as oils, as part of a healthy diet. Furthermore, the consumption of red and processed meat, sugary foods and beverages and refined grains are associated with adverse health effects and their avoidance is recommended. (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). This view is consistent with that of the WHO's International Agency for Research on Cancer, which categorized red meat as possibly carcinogenic (Group 2A) and processed meat as carcinogenic (Group 1) (WHO IARC, 2015).

The Dietary Guidelines for Americans state that in terms of dairy, plant-based alternatives derived from soy are fortified with calcium, vitamin A and vitamin D. Soy products, legumes, nuts, seeds and whole grains provide the protein necessary for a healthy diet in the context of vegetarianism. In addition, the equivalents of foods of animal and seafood origin with plant foods are provided.

Apart from its impact on human health, the link between dietary patterns and many different environmental issues has also been highlighted. Some of these major problems related to food production are the decline in biodiversity, soil erosion, land and water pollution, greenhouse gas emissions and the waste of the Earth's resources. Acting in combination, these parameters contribute greatly to environmental degradation, global warming and, in general, to what we call climate change (Marlow et al., 2009).

More specifically, the food supply chain is responsible for 26% of anthropogenic GHG emissions, corresponding to about 13.7 billion metric tons of carbon dioxide equivalents (CO2eq). Food production accounts for about 32% of global terrestrial acidification and about 78% of eutrophication. The farm stage generates 61% of food GHG emissions, 79% of acidification and 95% of eutrophication, both of which phenomena lead to biodiversity loss and the destruction of natural ecosystems. In addition, 43% of habitable land (i.e. that which is not desert and not covered by ice) is used for the needs of the agricultural system. Of this percentage, 87% is used for food. Two thirds of water withdrawals are used for irrigation, which returns less water to rivers and groundwater than other water uses and is more intense in dry periods and areas, reaching 90-95% of global water use weighted by water scarcity (Poore & Nemecek, 2018).

The link between these complex environmental challenges and food production has been recognized and is of growing concern to researchers, scientists and international organizations. In the search for an environmentally sustainable way to meet the nutritional needs of the world's growing population, changing eating habits has emerged as a good solution. Incorporating more plant-based foods into the diet, reducing animal-based foods and consuming calories at a healthy level can contribute immensely to sustainability (Clark et al., 2020). Vegan and vegan diets produce fewer greenhouse gas emissions and help reduce land and water use while contributing to good health (Willett et al., 2019). Analyzing a number of environmental parameters, namely the use of water resources and energy, the application of chemical fertilizers and pesticides, waste production and land degradation, and then comparing plant and animal foods, Marlow demonstrates that the ecological cost of animal-based food is greater, as it requires 2.9 times more water, 2.5 times more energy, 13 times more fertilizer, and 1.4 times more pesticides than did the vegetarian diet. The data and findings of this research concern the USA, however, as it is pointed out, they agree with corresponding research findings conducted in Europe, Japan and Australia. (Marlow et al., 2009).

Another issue linked to climate change is the spread of zoonoses. Deforestation, land shifts, habitat alterations, and global warming are all contributing to changes in ecosystems, which in turn can lead to the emergence of zoonotic diseases. Such examples include Ebola virus disease, which has been linked to deforestation and habitat alterations, Nipah virus, which is associated with land use changes and agricultural intensification, and Lyme disease, which is linked to changes in forest ecosystems. When ecosystems are destroyed or altered, the animals that live there may be forced to move to new areas, bringing with them new pathogens that can infect humans. Additionally, when biodiversity declines, the remaining species may become more abundant, which can increase the risk of zoonotic spillover. For example, when large predators are removed from an ecosystem, smaller animals like rodents may become more abundant, increasing the risk of diseases (The Lancet Infectious Diseases, 2022)

The United Nations Environment Programme 2022 clearly states that animal-based foods cause the greatest environmental impacts. Consumption of meat, especially from ruminants, dairy products and some seafood have a huge environmental cost per kilogram of food and also per calorie and per gram of protein. On the other hand, plant sources of protein such as lentils, beans and peas can meet the nutritional needs of most of the population, with much smaller environmental impacts. Interestingly, one of the proposed actions to achieve the shift in dietary habits from animal- to plant-rich is the creation of dietary guidelines that are both health- and sustainability-driven (UN Environment Programme, 2022).

With consideration of these issues of health and sustainability in relation to nutrition, and the debate surrounding them, in this thesis we attempt to combine the consideration of both. On the one hand, by comparing 4 popular types of diets - USDA ('omnivore'), Greek ('Mediterranean'), simple Vegan and WFPB - in terms of the nutritional density of each of them. On the other hand, evaluating the same 4 types of diets in terms of environmental impact. Recognizing the importance of the other environmental challenges associated with dietary patterns, we focus on comparing the same 4 diet types in relation to their water footprint, i.e. the amount of water used to produce the food that compose each one.

## Materials and methods

Table 1. Sources of data

| Data | Source |
|---|---|
| Macro and micronutrient composition of foods per 100g (fat, calories, magensium,) | USDA FNDDS database (https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-download-databases/)<br>USDA National Nutrient Database for Standard Reference Legacy Release (SR Legacy)<br>USDA Global Branded Food Products Database (Branded Foods) (https://fdc.nal.usda.gov/) |
| Water footprint of foods | Value of Water Report: 47: The green, blue and grey water footprint of farm crops and derived crop products (Report47-Appendix-II.xlsx)<br>Value of Water Report: 48: The green, blue and grey water footprint of farm animals and animal products (Report48-Appendix-V.xlsx) |
| Daily menus (mainstream) | Provided by Registered Dietitians for previous thesis (Bora, 2021) |
| Daily menus (Greek) | |
| Vegan | |
| Whole food vegan | Modified Vegan menus |

## PART ONE: CONCEPTUAL FRAMEWORK

# 1. Nutrient Density

## 1.1 Definition of nutrient density

The use of nutrient density to evaluate adequate nutrient intake in relation to energy needs was first introduced in 1998, with the concept of 'desirable nutrient density' (WHO, 1998). In the same year, a joint FAO/WHO consultation report suggested the use of nutrient density in the assessment of diets in order to establish and implement food-based dietary guidelines (FBDGs), that promote the health and well-being of individuals and populations globally (FAO/WHO, 1998).

In broad terms, nutrient density is understood as the nutrient content of a food or beverage, expressed per reference quantity, which can be 100 kcal, 100 grams, or per serving size. Although the per weight nutrient density is mostly used on food packaging, it does not convey information on calorie density, i.e. nutrients relative to energy. This is important as food consumption can be seen as a maximization problem within an energy constraint. Thus the most common measure in the research literature is the nutrients to calories ratio. For example, for example, milligrams of Vit C in 100 calories. Arguably the per energy nutrient density is a way to identify foods or food groups that are high in essential nutrients such as vitamins, minerals, fiber, and protein, while being relatively low in calories. (Drewnowski et al., 2019).

Foods and beverages that contain nutrients linked to negative health outcomes and non-communicable diseases, such as added sugar, saturated and trans fats, and sodium, are widely considered to be non-dense nutritionally (i.e. they have low nutrient density and high calorie density). Such foods, such as refined grains, fats and sweets are often and very energy-dense, while being poor in vitamins, minerals and other beneficial micronutrients. Hence, the energy they provide is described as "empty calories". High consumption of the latter has been shown to be linked to the global spike in obesity and diabetes rates. On the other hand, some energy-dense foods, such as nuts and seeds, are considered nutrient-dense due to their concentration in several essential nutrients (Drewnowski, 2005).

It is also important to consider that people very rarely consume individual foods. In fact, what happens is that they prepare recipes, mixed dishes, or serve a variety of foods in a single meal or snack. Such recipes usually consist of both nutrient-dense foods and non-nutrient-dense foods mixed together. For this reason, it may be more useful to consider the nutrient density of the entire diet, rather than individual foods, when evaluating the overall nutritional quality of a person's diet. Nevertheless, the approach of assessing the nutrient density of individual foods, as opposed to whole diets, should not be completely dismissed, as it can be helpful in identifying and substituting certain foods with more nutrient-dense options. (Nicklas et al., 2014).

In the context of “desirable nutrient density” introduced in 1998 in the WHO Programme of Nutrition, the denominator of the nutrient density expression used the recommended energy intake. Later, the concept of “critical nutrient density” was introduced, replacing the denominator with the reference recommended energy requirements that refers to a specific segment of the population, such as infants, toddlers, and lactating women. In general, “critical nutrient density” refers to nutrient concentrations that only provide the daily recommended intake of a nutrient at the caloric intake where the average energy requirements are met (Solomons & Vossenaar, 2013).

The denominator in the expression of nutrient density is the daily requirement for each nutrient, based on the consumption of calories to meet energy needs. The latter vary for each individual depending on factors such as gender, age and physiological status. Dietary Reference Intakes (RDI's) are the quantitative recommendations for nutrient intakes and are used as reference values and standards for estimating and assessing nutrient intakes for healthy individuals according to gender, age, and status (lactation, pregrancy).

RDI's include the Estimated Average Requirement (EAR), which is the mean requirement of a group of a particular gender and age, the Recommended Daily Allowances (RDA), which is the average daily intake that meets the nutritional requirements of almost 98% of a particular sex, age and physiological state. The RDAs are mostly calculated as EAR ±2 SDs. Also included in the RDI's is the Adequate Intake (AI), which is an average intake in a group of healthy individuals that is assumed to meet their nutritional needs, and the Tolerable Upper Level (UL), which defines the maximum level of consumption that does not cause adverse health effects (Dwyer, 2003). Usually it is difficult to consume nutrients above the UL without the use of nutritional supplements.

## 1.2 Nutrient Density in the Dietary Guidelines for Americans

The nutrient density approach as a measure of food and dietary assessment has been particularly useful in the development of the Dietary Guidelines for Americans (DGAs), whose purpose is to provide science-based nutritional advice. The DGA have been published every five years since 1980 and have served as a compass for both public policy formulation and for educating people about diet planning in the US and globally. The concept of nutrient density has evolved and enriched remarkably within the DGA framework.

The 2005 DGAs were the first ones to include the concept of nutrient density. Specifically, they encouraged the consumption of nutritionally dense foods, which they defined as those that combine significant amounts of micronutrients (vitamins and minerals) and relatively low calories. In this way, individuals can meet their nutrient needs, reducing the risk of chronic disease from adverse nutrient intake and reduce caloric overconsumption. It is noted in the DGA that Americans generally do not choose nutritionally dense foods. Furthermore, it is emphasized that the greater the consumption of non-nutrient-dense foods and beverages, the more difficult it becomes to meet nutrient needs, while avoiding weight gain (U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2005).

The 2010 DGAs maintain the concept of nutrient density and add the absence of calories coming from added solid fats, sugars and refined starches as a characteristic of nutrient-dense foods. They also provide a list of foods that are considered nutrient-dense and whose consumption promotes nutritional adequacy and keeps calorie intake balanced. Namely, the consumption of all vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry- provided they have been prepared without added fats and sugar, is highly recommended as part of a health-promoting eating pattern (U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2010).

The 2015 DGAs place emphasis on variety, by encouraging the consumption of nutritionally dense foods across and within all food groups, in the recommended amounts. In addition, recognizing the need for a large portion of the population to shift their current dietary patterns, special emphasis is placed on substitutions. This encourages the selection of nutrient-dense foods to replace less healthy ones. This helps to meet nutrient needs while keeping energy intake in moderation. Overall, the 2015 DGAs suggest that making substitutions towards nutrient density and including all food groups, combined with keeping calories low, is a major contribution to positive health benefits (U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2015).

Nutrient density has a central role in the most recent version of the DGAs. In particular, the 2020 DGAs encourage healthy eating patterns, customized to personal preferences as well as cultural aspects. Moreover, an important addition is the special emphasis given to each stage and phase of life, as well as to the period of pregnancy and lactation. The introduction of a variety of "nutrient-dense" foods as complimentary foods to human milk is encouraged for infants at around 6 months of age. In this context, it is highlighted that preferences and patterns established at an early age have a strong influence on later dietary choices, and thus on overall health (U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2020).

### 1.3 Challenges

Nutrient density has been widely featured in the scientific literature and public policies for over two decades. Although its usefulness as a tool in efforts to reduce chronic disease through the promotion of healthy eating patterns is generally recognized, there are several challenges regarding its definition and content. To begin with, the term remains ambiguous and lacking a solid and universal definition; also lacking isthe establishment of specific criteria and indicators of which foods are nutrient-dense.

This lack of a universal definition and criteria leads to contradictions and inconsistencies around nutrient density. One such example is the listing of lean meat as a nutritionally dense food in DGAs since 2010. However, this may not always be the case, as lean meat contains more saturated fatty acids compared to other food groups and in addition some of the nutrients it is rich in, such as vitamin B12 and iron, are not usually taken into account in nutrient profiling. Also, DGAs include all fruits and vegetables in the list of nutrient-dense foods. Nevertheless, the nutrient density of fruits and vegetables may vary considerably and is probably underestimated due to the exclusion of phytochemicals from the definition.

Another point that should be carefully addressed is that the way in which the nutritional approach is communicated to consumers. Emphasis should be placed on avoiding the stigmatization of specific foods as good or bad, which may lead to the exclusion of ceratain food groups.

Overall, there are several questions and inherent complexities that need to be resolved in order to arrive at a science-based definition of nutrient density that is both sustainable and also economically and culturally relevant to consumers in order to assist in making more educated choices. Besides the challenges, there are also opportunities and space for the nutrient density approach to evolve and increase its effectiveness (Nicklas et al., 2014).

## 2. Nutrient profiling

## 2.1 Definition of nutrient profiling

Nutrient profiling is a relatively new technique employed to classify, rate, or rank foods and beverages based on their nutritional value per reference amount. Apart from individual foods, it can be applied to evaluate meals, menus and whole diet plans (WHO, 2010). Nutrient profiling, compared to the concept of nutrient density, can be used to evaluate nutritional value, with an emphasis on the quantitative dimension, through the use of models and algorithms.

The most common use of nutrient profiling is for developing food labelling systems to provide guidance to consumers in selecting healthier foods. These systems, in order to deliver maximum results, need to be both science-based and consumer-friendly, which means providing nutritional information in a simple way which the majority of consumers can understand. In this way they can make it easier to compare within and across food categories (Wartella et al., eds. 2011).

Nutrient profiling can also be used to assess the affordability and sustainability of foods. The inclusion of food prices in nutrient density calculations adds an important dimension to the science of nutrient profiling, which is of great interest to consumers. Thus, the foods with the highest nutritional value per cost unit can be identified. The relationship between the nutrient density of foods and environmental problems such as carbon dioxide emissions has also been studied (Drewnowski & Fulgoni, 2014; Perignon et al., 2017).

In addition, nutrient profiling can help in the formulation of public health policies, as well as influence the food industry by providing a scientific basis for the introduction of regulations and restrictions both at national and regional level. One such example is the nutrient profile model proposed by the WHO Regional Office for Europe, for Member States to utilize when developing policies to restrict food marketing to children (WHO Europe, 2015a).

## 2.2 Nutrient profiling models

Nutrient profiling models provide calculations of the nutrient density scores of foods, using algorithms that can be based on different reference amounts, such as 100 grams, 100 calories, or per serving of food. Nutrient profiling models are based on beneficial nutrients or nutrients to limit or a combination of both, and the balance between them provides ratings for foods. Among beneficial nutrients we commonly find protein, dietary fiber, and various vitamins and minerals; nutrients to limit include free or added sugars, saturated fat, and sodium. They are usually food-based, but some models may consider food groups.

Nutrient profile models can be distinguished into compensatory or noncompensatory. The former balance nutrients to encourage against nutrients to limit, while the latter focus solely on nutrients to limit (Drewnowski et al., 2019). They can also be distinguished according to the descriptions they produce, which may refer to the nutritional value (e.g. low fat, source of fiber, energy dense, nutrient poor) or to the health effects attributed to their consumption (e.g. healthy, less healthy) (WHO, 2011).

In order for nutrient profiling models to serve the purpose of improving the nutritional quality of the food supply and promoting public health most effectively, they should be transparent, objective, and free of conflicts of interest. Thus, they need to be based on published algorithms and public nutrient composition data from high quality databases. In addition, it is essential that they are validated using independent standards for a healthy diet and compared with selected health outcomes, to ensure that they accurately reflect the nutritional quality of food.

Despite efforts to develop a nutrient profiling system that meets scientific criteria and helps to select foods associated with positive health outcomes, standardizing procedures for developing, testing, and validating nutrient profiling models remains a challenge. There is largely a lack of consensus on what the best approach to nutrient profiling is, especially regarding the nutrients considered and the scoring system (Drewnowski & Fulgoni, 2014).

In the following section three Nutrient Profiling Models are presented– the Healthy Eating Index (HEI), the Healthy Diet Index (HDI) and the Nutrient Rich Food Index (NRF). These particular Models were chosen because they are very popular in the literature and also because they have a wide range of practical usefulness, since the first two are used in the USDA and WHO dietary guidelines, while the Nutrient Rich Food Index is important to present because it is the basis of the index we built to compare the four types of diets in this thesis.

## 2.3 Healthy Eating Index

The Healthy Eating Index (HEI) is a measure that evaluates the overall diet quality, which can refer to an individual or a population. It is based on the DGAs and measures how well a food set aligns with the key recommendations of the former. The original HEI was released in 1995 by the USDA Center for Nutrition Policy and Promotion (CNPP). The original HEI had ten components, that included five food groups (grains, vegetables, fruits, milk, and meat), four nutrients (total fat, saturated fat, cholesterol, and sodium), as well as one measure of variety in food intake. As each of the components has a score of 0-10, the total score of the index can range from 0-100 (Kennedy et al., 1995). As new editions of DGAs are published every five years, the HEI has also been updated several times to reflect changes in DGAs and they capture the evolution of nutrition science on this topic.

The HEI has a wide range of uses and is among the most popular indicators of nutritional quality. To date it has been used in hundreds of publications to assess a variety of issues such as food intakes, availability, and marketing. The HEI is a useful tool for researchers, policymakers, and healthcare professionals to monitor the diet quality of the population, and also population subgroups, to inform nutrition education and intervention programs, and to evaluate the impact of policy changes on diet quality (Krebs-Smith et al., 2019).

The most recent version of the HEI is the 2020-2025 version and assesses compliance with the corresponding version of the DGAs. The most recent version of the HEI is the 2020-2025 version and assesses compliance with the corresponding version of the DGAs. It consists of thirteen components, including nine adequacy components (total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids), whose consumption in recommended amounts is encouraged as health promoting, and four moderation components (added sugars, saturated fats, sodium, and alcohol), whose consumption should be limited for achieving improved health outcomes. Furthermore, each component can score from 0 to a maximum of 5 or 10 points, with the total possible score ranging from 0-100. The scoring system is based on the density approach, which means that the amount of each component is standardized to a reference amount per 1,000 calories. The reference amounts used in the 2020-2025 HEI version are based on the 2020-2025 DGAs (Shams-White et al., 2023).

### 2.4 Healthy Diet Index

The Healthy Diet Index (HDI) is a tool used to assess compliance with the dietary guidelines issued by the WHO. It was first introduced in 1990, following the WHO guidelines for a healthy diet and the prevention of chronic disease. The original HDI had nine components (saturated fatty acids, polyunsaturated fatty acids, protein; complex carbohydrates, dietary fiber, fruits and vegetables; pulses, nuts and seeds, monosaccharides and disaccharides; cholesterol). For each component a dichotomous variation was generated, meaning that if intake was within the recommended amount, it was coded as 1, otherwise, as 0. Thus, the HDI was the sum of all dichotomous variables (Huijbregts et al., 1997).

In 2003, the HDI was updated for the first time following the publication of the WHO dietary guidelines, and has been updated several times to date as the science of nutrition and dietary recommendations evolve (Kanauchi & Kanauchi, 2018). The most recent version of the HDI is the one based on the current WHO recommendations. It includes eleven components, five are health-promoting (fruits and vegetables, beans and other legumes, nuts and seeds, whole grains, dietary fiber) and six components to limit (total fat, saturated fat, dietary sodium, free sugars, processed meet, unprocessed red meat). The index is calculated as the sum of the components and the total score can be 0-11 (Herforth et al., 2020).

Unlike other popular indicators that assess diet quality at the population level, for example the HEI or the Mediterranean Diet Score (MDS, see below), HDI has the advantage of being designed for worldwide use and therefore it provides a standardized method for evaluation and comparison among different cultures. This can be useful for identifying areas where dietary interventions may be needed to improve public health. Despite this major advantage, the fact that it is based on a limited number of nutrients and food groups may not capture all aspects of a healthy diet (Jankovic et al., 2014).

### 2.5 Nutrient Rich Food Index

The Nutrient Rich Food Index (NRF) is a family of nutrient profiling models, which can be applied to assess the nutrient density of individual foods, as well as entire diets. They are usually based on two sub-scores, NR and LIM. NR refers to the nutrients to encourage, while LIM is based on three nutrients to limit. In other words, the NRF score takes into account nutrients be consumed in adequate amounts and nutrients to be consumed in moderation, and balances them to provide a comprehensive evaluation of a food's or diet’s nutrient density (Drewnowski et al., 2019).

In 2006, NRF 9.3 was introduced, which included nine nutrients to encourage (protein, fiber, vitamin A, vitamin C, vitamin E, calcium, iron, potassium and magnesium) and three nutrients to limit (saturated fats, sugars, and sodium). There are several variations of the score, depending on the positive nutrients they include, which range from 3 to 23. In addition, the basis for the calculations is 100 kcal and always remains standard.

This is a feature that gives NRF an advantage over other Nutrient Profiling models which calculate nutrient density on the basis of 100 g of food. This is because scores based on weight reflect more closely the energy density than the nutrient density per 100 kcal. Thus, compared to other models, it manages to provide a more complete picture of the nutritional value of a food or diet. Some additional features that make the NRF an effective tool are that (a) it is based on principles and guidelines that promote public health and (b) remains quite flexible and adaptable to updates. It is also a transparent method of calculating nutrient density, and is well documented in the literature (Drewnowski et al., 2019).

Recognizing the recent shift in the focus of scientific literature and dietary guidelines from individual nutrients to food groups and dietary patterns, Drewnowski and Fulgoni introduced a new hybrid NRF (NRFh) score in 2020 which contains food groups as well as nutrients. This new model was developed to combine both nutrient and food group components and is based on three sub-scores: NRx, MPy, and LIMz. NRx is based on a variable number of nutrients to encourage, MPy is based on a variable number of MyPlate food groups to encourage, and LIMz is based on a variable number of nutrients to limit. The new NRFh score is expressed as follows:

$$NRFh = 100*(NRx + MPy - LIMz)$$

Specifically, two models were developed. The NRFh3:4:3 score, with six nutrients and four food groups (fiber, potassium, PUFA+MUFA, whole grains, dairy, fruit, nuts and seeds, saturated fat, added sugar, sodium), and the NRFh4:3:3 score, with seven nutrients and three food groups (protein, fiber, potassium, PUFA+MUFA; whole grain, dairy, fruit; saturated fat, added sugar, sodium). In the same study, the hybrid NRF scores, were validated against an independent measure of nutritional quality, the HEI, based on multiple regressions. Both the new hybrid models correlated well with HEI-2015. These results are highly significant because they indicate that hybrid NRF scores are transparent and are accurate measures in assessing nutrient density of foods and diets. Such nutrient profiling models could be particularly useful as part of dietary guidance (Drewnowski & Fulgoni, 2020).

# 3. Prevailing eating patterns

## 3.1 Short description of dietary patterns

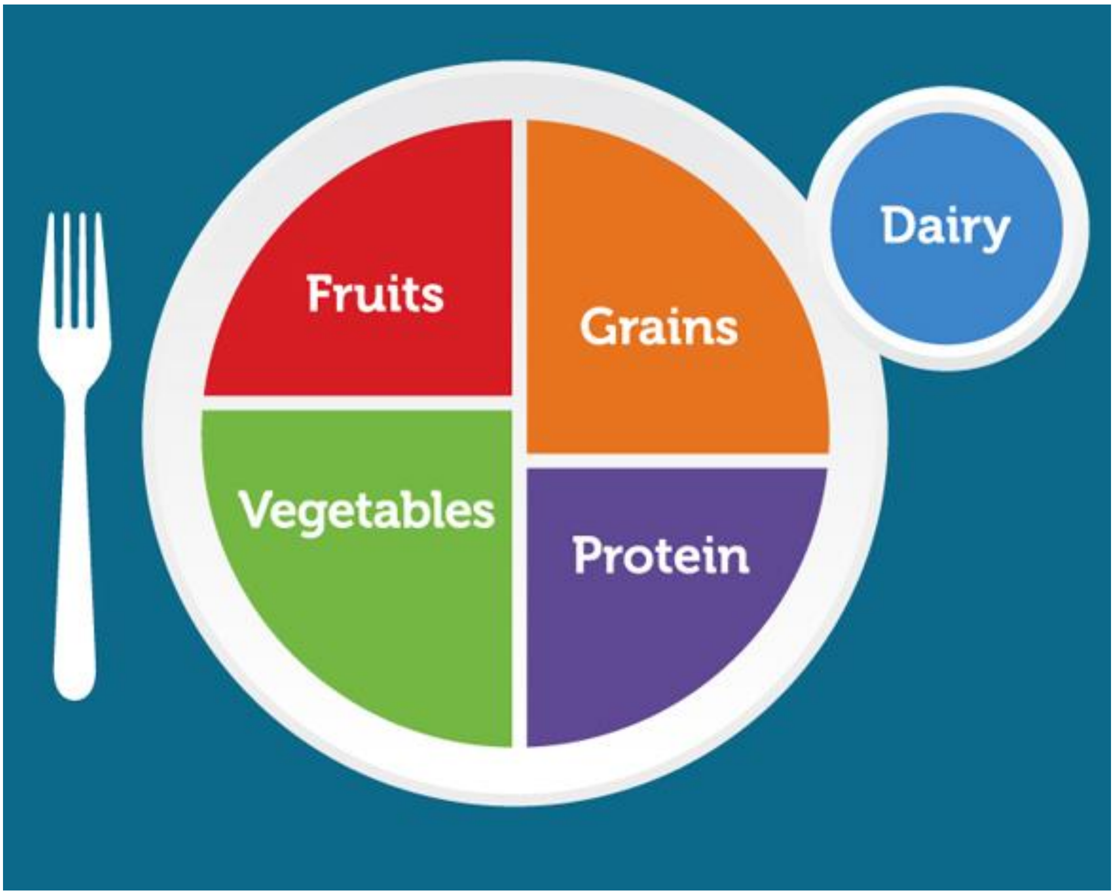
### *3.1.1 Omnivorous or mixed diet*

An omnivorous or mixed diet includes a variety of foods that are both animal and plant-based. It is characterized by dietary patterns that combine animal and plant sources from all food groups, without omitting or excluding any of them. The omnivorous diet is the most popular type of diet in western societies and it can vary widely based on personal preferences, regional factors, and cultural factors (Holler et al., 2021).

In 2011, the USDA's Center for Nutrition Policy and Promotion introduced MyPlate (Figure 1) to replace MyPyramid. The plate concept is intended to be a simpler and more practical way to display the main principles of a healthy diet, than the previously used pyramid concept. MyPlate provides healthy dietary recommendations, by presenting the DGAs at a glance in a visually easy way. It serves as a new food guidance system to help consumers make healthier food choices.

MyPlate includes five food groups: fruits, vegetables, grains, protein foods and dairy. It uses an image of a place setting for a meal to illustrate the recommended proportions of each food group in a healthy diet. Half of the plate is taken up by fruits and vegetables, while the other half is taken up by grains and protein foods. In addition, MyPlate a portion of dairy products preferably low-fat or fat-free, is included (Uruakpa et al., 2013).

Figure 1. USDA's MyPlate

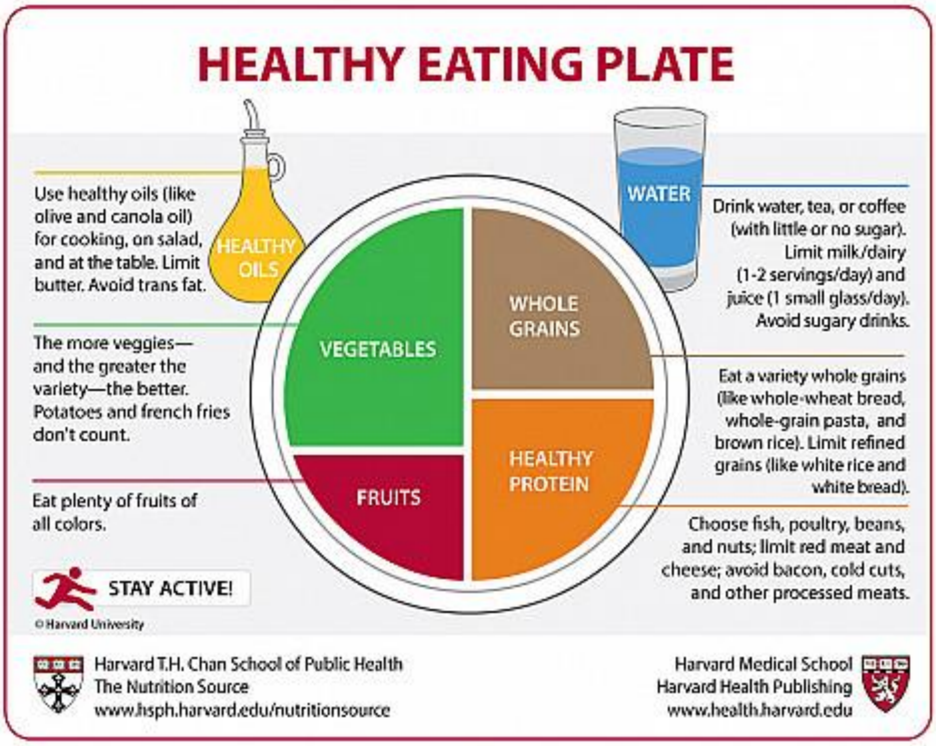



*Source*: https://www.myplate.gov/

It is important to note that MyPlate has replaced the "Meat and Beans" group from MyPramid with "Protein Foods" group. This change allows this food group to encompass all of the protein-rich foods present in the US diet and consequently encourages consumers to consider alternative options to meet their protein requirements, including plant-based sources such as legumes, nuts, and seeds. Furthermore, both MyPlate and the 2010 DGAs directly recommend variety regarding protein foods, in order to broaden the understanding of the types of foods that can contribute to protein intake, beyond just meat and poultry (Fehrenbach et al., 2015).

Following the launch of MyPlate, the Harvard School of Public Health (HSPH) introduced the Healthy Eating Plate as a better guide to planning a healthy and balanced diet in 2011. It represents an omnivorous diet that includes four food groups: fruits, vegetables, whole grains, and protein. Half of the plate is taken up by fruits and vegetables, and the other half by whole grains and healthy protein. There are three major deviations from MyPlate: (1) the concept of "healthy" protein conveys the connotation that not all kinds of protein foods are healthy; (2) the elimination of dairy signifies that dairy is not necessary for good health; (3) the concept that processed grains (white bread, pizza dough, cookies, etc.) are not part of a healthy plate; any grains should be eaten whole. The proportions are similar to those recommended in MyPlate (Harvard School of Public Health, 2023).

Figure 2. Harvard's Healthy Eating Plate




*Source*: https://www.hsph.harvard.edu/nutritionsource/healthy-eating-plate/

There are, however, substantial differences between the two. The dairy serving, which was included on MyPlate as the fifth recommended food group, has been replaced with a glass of water. This suggests that dairy is not essential food; dairy products, juice and sugary drinks should be limited and the healthy source for hydration is water or beverages such as coffee and tea. In addition, the Healthy Eating Plate recommends the consumption of certain vegetable oils in moderation as a source of "good" fats. The fact that the Healthy Eating Plate specifically recommends "healthy protein" indicates that not all protein foods are healthy; certain protein-rich foods such as red and processed meats and cheese do not constitute healthy options. In addition, the Healthy Eating Plate icon features a running figure, which highlights the importance of combining exercise with a balanced diet to promote health. A similar figure existed in MyPyramid, but was not included in MyPlate.

### *3.1.2 Mediterranean Diet*

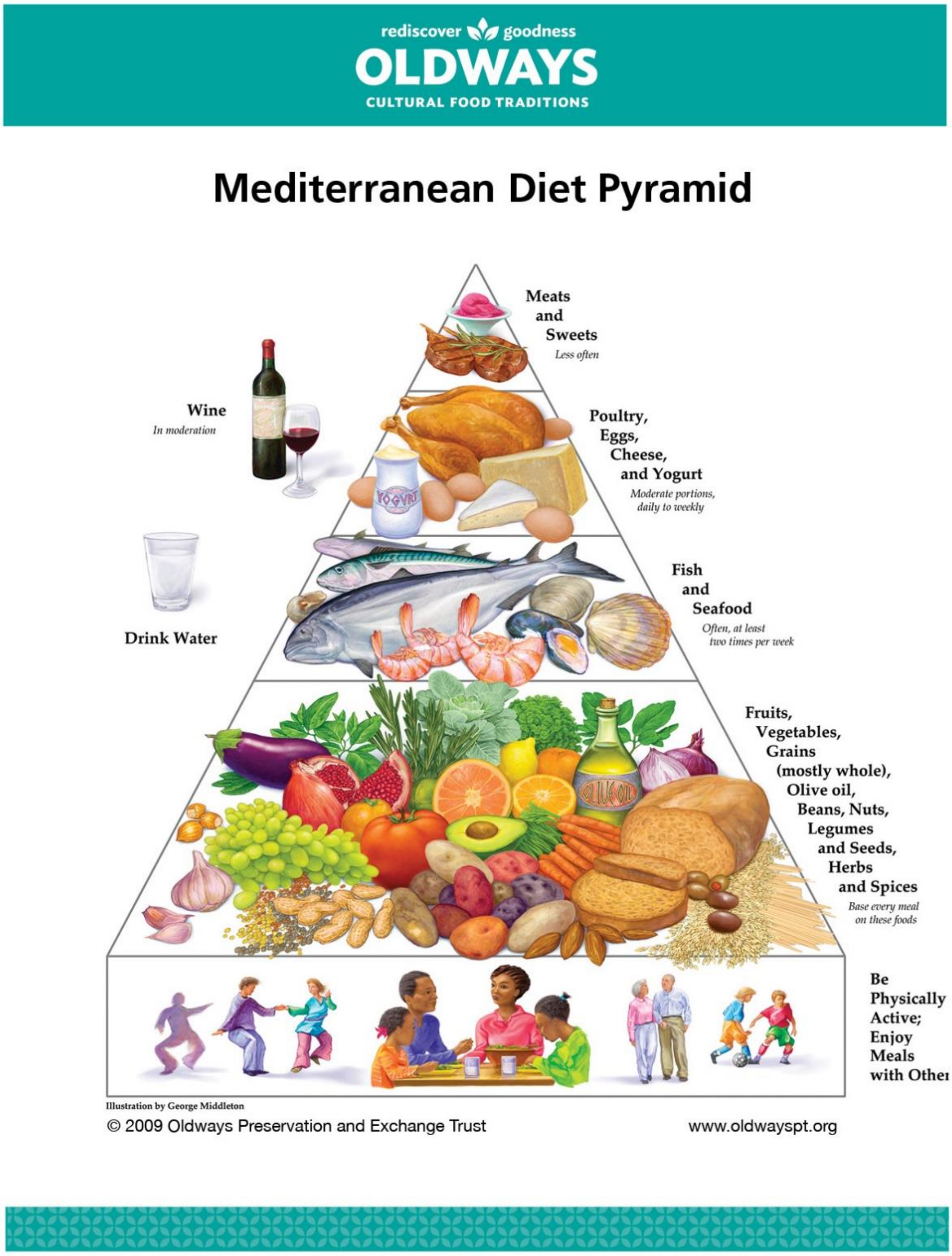
The Mediterranean Dietary Pattern (MDP) is the type of diet which was traditionally followed with some variations in the countries around the Mediterranean basin, such as Italy, Greece, Albania, Spain, France, Lebanon, Morocco, Portugal, Syria, Tunisia, and Turkey, among others. However, it has gained popularity worldwide as a dietary pattern with many health benefits.

The Mediterranean diet was first defined and studied in greater depth in the 1960s, as the dietary pattern found in the olive-grown regions of Greece and southern Italy (Martínez-González & Sánchez-Villegas, 2004).

The analysis of the composition of the diet followed on the island of Crete in the late 1940s is particularly interesting. Only 7% of the total caloric intake comes from animal sources, i.e. on the basis of a 2,000 kcal diet, animal products account for 140. In addition, 5% of total calories come from the consumption of free sugars. On the other hand, foods such as cereals, nuts, legumes, vegetables and fruits account for 61% of calories, i.e. on the basis of a 2,000 kcal diet, these plant foods account for 870 calories (Nestle, 1995). From this analysis it appears that the traditional Cretan diet is very similar to the modern vegan diet, which also has multiple health benefits. However, the Mediterranean populations have drifted away from the authentic Mediterranean diet, and this is something that is related to the increasing rates of non-communicable diseases, as well as obesity.

In the literature, the basic components of the Mediterranean diet as is perceived today show only slight variations. In terms of food quantities, there are some variations, represented by pyramids. The first pyramid was published in 1993 by Oldway's Preservation and exchange Trust and was updated in 2009. The Greek Dietary Guidelines based on the Mediterranean diet have also been expressed in a pyramid model. Also in 2010, a similar pyramid was introduced by the Mediterranean Diet Foundation.

Figure 3. Oldways's Mediterranean Diet Pyramid




*Source*: Oldways Mediterranean Diet Pyramid | Oldways Mediterranean Diet Pyramid (oldwayspt.org)

The characteristics of the Mediterranean diet as researched in the 1950s are that most of it is plant-based, as there is an abundance and high frequency of consumption of fruits and vegetables, cereals, beans, nuts and seeds. Fresh fruits replace desserts, as the latter are very limited. The intake of dairy products, especially cheese and yoghurt, is low to moderate. Virgin olive oil accompanies almost all meals, being the main source of fats and occupying 30%-40% of the total energy intake. Protein requirements are largely met from plant sources such as legumes, fish and poultry, while the consumption of red or processed meat and eggs is very low. Although animal foods are included in the diet, their combined percent of calories was only 7%. For comparison, the current percentage of calories from animal protein is 18% globally, and ranges from 7% (Africa region) to 32% (US and Australia). In general, the foods that make up the Mediterranean diet are mostly of plant origin, unprocessed, locally and seasonally grown foods. Also, salt is used in small amounts and instead herbs and spices are added to recipes to give a better flavor. Alcohol, in particular red wine, is consumed daily with meals, but in moderate amounts.

The Mediterranean diet has been shown to be associated with improved health outcomes. It has been associated with lower mortality from all causes and has been proven to be beneficial in preventing several non-communicable diseases. Specifically, it can have a significant impact on reducing the risk of type 2 diabetes, by improving glycemic control and insulin sensitivity. Greater adherence to a traditional Mediterranean diet offers a protective effect against type 2 diabetes, as it helps to improve insulin sensitivity and reduce inflammation, which are key factors in the development of the disease (Boucher, 2017).

Also, the Mediterranean diet, has been consistently associated with a reduced risk of cardiovascular disease and stroke. As it is rich in antioxidants, it is linked with lower LDL cholesterol, triglycerides, and blood pressure (all of which are risk factors for heart disease) and has been shown to reduce non-fatal coronary events (Davis et al, 2015; Martínez-González et al., 2019).

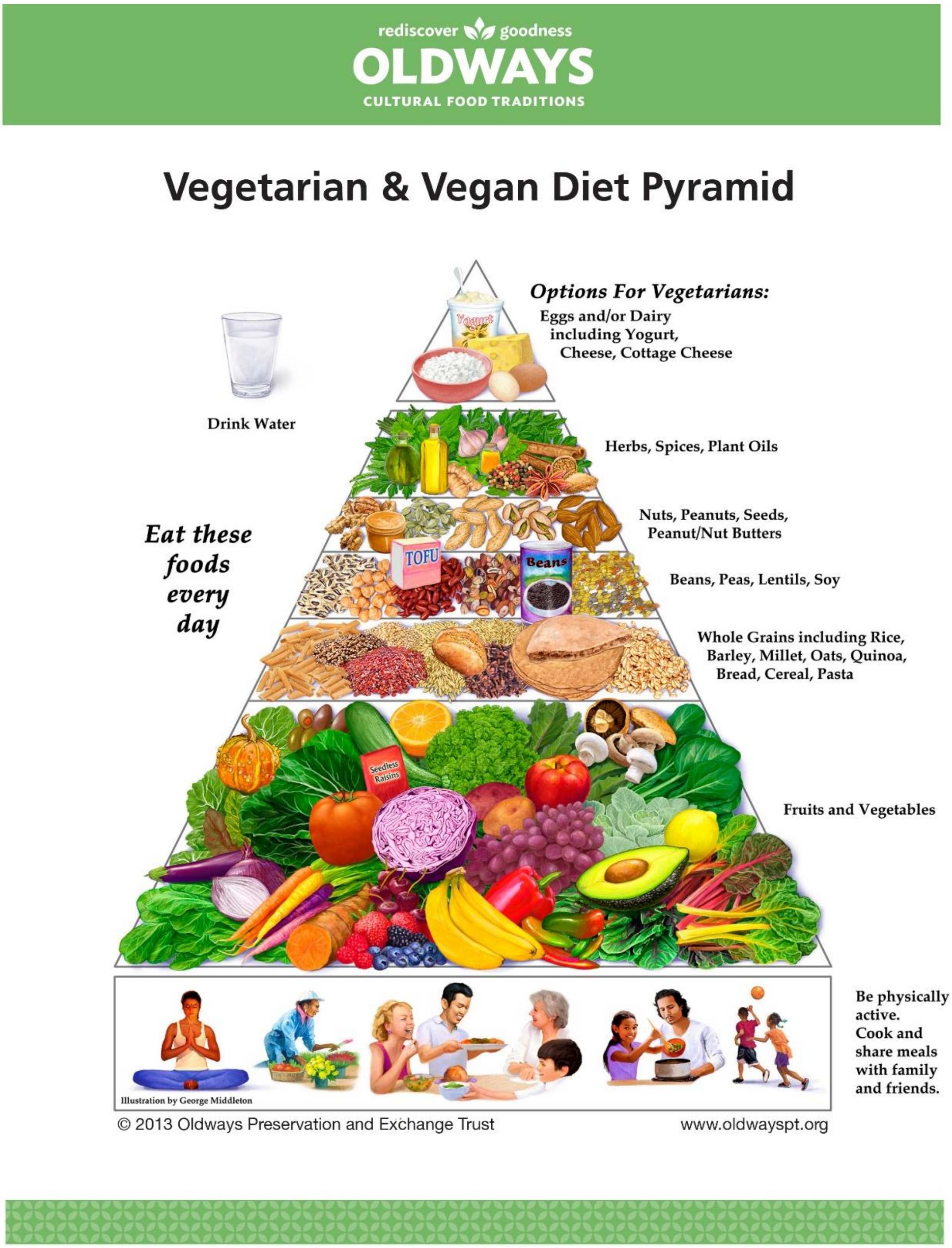
Finally, a Mediterranean dietary pattern can help control weight and reduce the risk of obesity, which according to the WHO has reached epidemic proportions (WHO, 2021). As it encourages the consumption of whole fruits, vegetables and cereals, the Mediterranean diet provides large amounts of fiber, which can help promote feelings of fullness and reduce overall calorie intake (Davis et al, 2015).

### *3.1.3 Vegetarian Diets*

A vegetarian diet is a type of diet that excludes the consumption of meat and products that contain meat. The dietary practices within the range of vegetarian diets are several, depending on the types of foods they exclude, but are typically based on vegetables, fruits, legumes, grains, seeds and nuts. Four of the main categories reported in the literature are the following: the pesco-vegetarian or pescatarian diet, which includes fish and seafood; the ovolactovegetarian diet, which excludes meat but not foods of animal origin such as dairy products or eggs. Specifically, the ovolactovegetarian diet includes two subcategories: the lactovegetarian diet, which excludes meat and eggs but allows dairy products, and the ovovegetarian diet, which excludes meat and dairy products but includes eggs. Another subcategory of the vegetarian diet is the flexitarian or semivegetarian diet, which is plant-based but allows for the consumption of meat, poultry or fish occasionally or the exclusion of red meat but not white meat, and the strict vegetarian or vegan diet, which excludes all animal products and their derivatives (Hargreaves et al., 2023).

A diet free from animal origin foods is called a vegan diet. It is mostly uptaken due to ethical considerations about animals (whether it is fair to use animals as means to human ends). Vegans consume a wide variety of plant-based foods such as fruits, vegetables, whole grains, legumes, nuts, and seeds. Alternatives to the meat and dairy are quite popular in all variants of the vegetarian diet. These alternatives are processed foods made from plant-derived ingredients and are developed to approximate the texture of meat and substitute for it. Plant-based ingredients in these processed foods come primarily from soy, wheat, mushrooms, and also from legumes e.g. peas, lentils, lupines, and chickpeas.

Figure 4. Oldway's Vegetarian and Vegan Diet Pyramid




*Source*: https://oldwayspt.org/resources/oldways-vegetarianvegan-diet-pyramid

Plant-based alternatives to milk are basically water-soluble extracts from legumes, cereals such as oats and rice, pseudo-cereals such as quinoa, nuts such as almonds, hazelnuts, walnuts, seeds such as sesame, sunflower seeds. They resemblethe texture of animal-based milks and are used in about the same way for most culinary preparations. Such products are becoming increasingly popular among the general population as they offer healthier, ethical, and environmentally friendly alternatives (Alcorta et al., 2021).

Vegetarianism has been practiced since ancient times, having been recorded in ancient Egyptian and Greek cultures. It is worth noting that for several centuries the vegetarian diet was known as the 'Pythagorean' diet, as Pythagoras, an ancient Greek philosopher and scientist, led the way in advocating vegetarianism. In earlier times, abstinence from meat was mainly rooted in religious and philosophical beliefs. Today, the prevalence of vegetarianism varies around the world. More specifically, in Asia, it is more popular than other regions of the world, with 19% of people adopting a vegetarian dietary pattern. In Africa and the Middle East, this figure is followed by around 16% of the population, in Central and South America it is 8%. The lowest rates are found in North America and Europe, where vegetarian diets are adopted by 6% and 5% of the population respectively. The lowest rates are found in North America and Europe, where vegetarian diets are adopted by 6% and 5% of the population respectively (Hargreaves et al., 2021).

The motivations for adopting a vegetarian diet differ. Concerns regarding the conditions in which animals are raised and slaughtered, as well as the belief that it is morally inappropriate to kill animals for human consumption, are among the main motivations for adopting some form of vegetarianism among Western societies. In addition, many people follow a vegetarian diet for the health and fitness benefits it offers. As a vegetarian diet can be lower in saturated fat and cholesterol, and higher in fiber and other essential nutrients, many individuals adopt it in order to reduce their risk for chronic diseases and achieve better health. Other reasons that encourage people to become vegetarian are environmental concerns, stemming from the association of vegetarianism with a number of environmental problems. Also, abstinence from eating meat may be the result of religious beliefs (Ruby, 2012).

Vegetarian diets have been shown to offer multiple health benefits. The official position of the American Dietary Association (ADA), is that a well-planned vegetarian or vegan diet is a healthy and nutritionally adequate choice, which can be extremely beneficial in the prevention and treatment of certain diseases. In addition, properly planned vegetarian and vegan diets are suitable for all stages of life, including pregnancy, lactation, infancy, and for athletes.

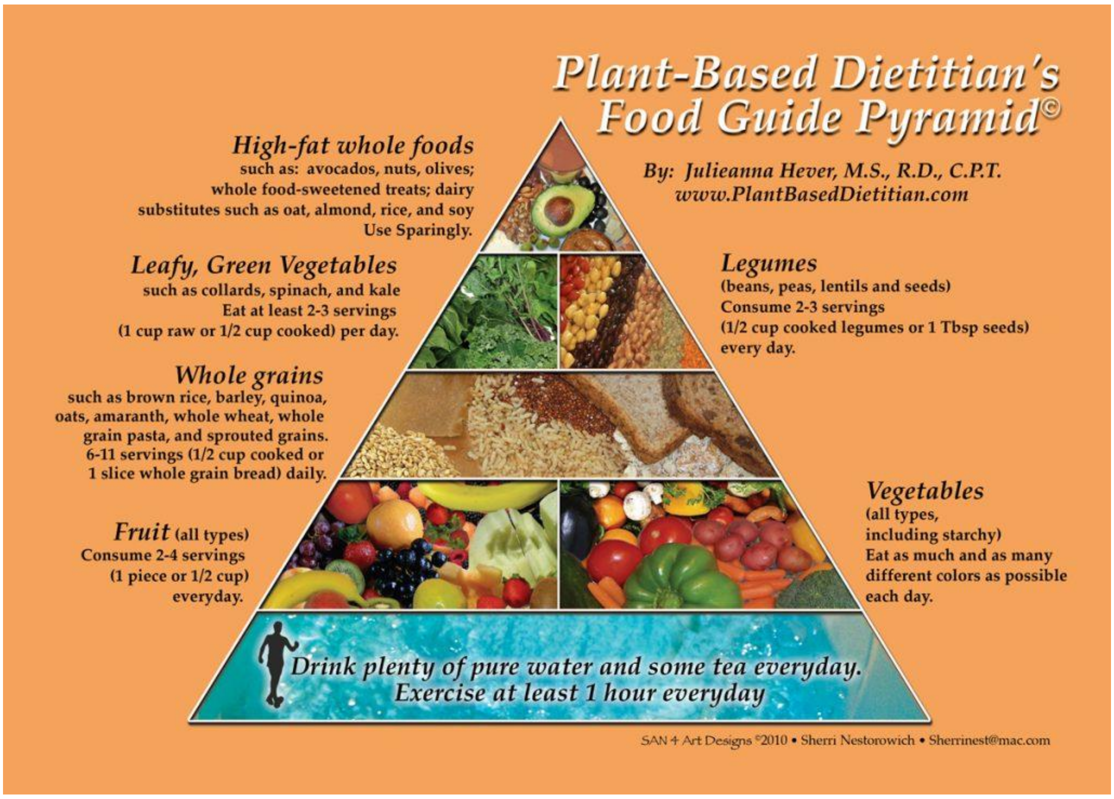
The condition of careful and appropriate planning of vegetarian diets is essential, because it is feared that unplanned vegetarian diets can be low in certain nutrients, such as protein, iron, calcium, vitamin D, vitamin B12, and omega-3 fatty acids, which are typically found in animal products. Therefore, it is important for vegetarians and vegans to ensure that they are getting enough of these nutrients from plant-based sources or supplements (American Dietetic Association, 2003).

However, vegetarian diets, due to their high content of fiber, vitamins, minerals and antioxidants, has been associated with a reduced risk of developing chronic diseases such as type 2 diabetes, and certain types of cancer such as colon, breast, and prostate cancer. It has been linked to lower blood pressure and cholesterol levels, lower risk of mortality from ischemic heart disease and improved overall cardiovascular health. Vegetarian diets are associated with lower Body Mass Index (BMI) and therefore reduced risk of obesity and improved weight management. In addition, they are rich in fiber, which is extremely beneficial for gut health, and can help to improve the balance of gut microbiota and reduce the risk of digestive disorders (Ruby, 2012; Alcorta et al., 2021) Apart from promoting physical health, vegetarian diets can also have a positive effect on a social level, developing in individuals a sense of belonging to a community, improving quality of life and contributing further to well-being and mental health (Hargreaves et al., 2021).

### *3.1.4 Whole Food Plant Based (WFPB) Diet*

The Whole Food Plant Based (WFPB) diet is a type of diet that includes plant-based foods in their most natural form, that is, whole, unrefined, and with little or no processing. It bears significant similarity to the vegan diet, but focuses on the dimension of health improvement rather than ethical considerations. Typically, emphasis is placed on the intake of a wide variety of cooked or raw fruits and vegetables, legumes, as well as whole grains, nuts and seeds in smaller amounts. These foods have low calorie density and high nutrient density. Meat, seafood, dairy, and eggs are excluded. Also, highly processed foods, refined sugars and refined grains, oils and fats are generally avoided (Tuso et al., 2013).

Figure 5. WFPB Diet Pyramid




*Source*: [Plant-Based Dietitian's Food Guide Pyramid – Food Pyramid (food-pyramid.org)]

The WFPB diet has been associated with numerous health benefits. As it is rich in fiber, vitamins, minerals, and antioxidants and low in animal protein, saturated and trans fats, it can be useful in preventing and treating a range of conditions. Specifically, it has been shown to have a positive effect on promoting weight loss and weight management and reduce the risk of obesity. Several studies have shown that people who follow a WFPB diet have a lower Body Mass Index and are less likely to be obese than those who consume animal and processed foods (Jakše et al., 2020).

Furthermore, the WFPB diet has been shown to have a protective effect against heart disease. It is associated with improved cardiovascular health and reducing overall and cardiovascular mortality. Lower blood pressure, improved lipid profiles and lower levels of LDL cholesterol, have been observed in people that follow a WFPB diet. Lifestyle changes that include a shift towards a WFPB diet, combined with moderate exercise and stress management, resulted in lower levels of LDL cholesterol and triglycerides levels, reduction in weight and body fat and avoiding revascularization for patients with severe but stable coronary artery disease (Ornish, 1998). Lifestyle changes have also been shown to decrease the stenosis diameter and in the frequency of angina episodes (Ornish et al., 1998).

It is also associated with significantly lower risk of developing type 2 diabetes. Many studies suggest that a WFBP diet may have a positive effect on the management of the disease, as it can contribute in insulin sensitivity and glycemic control of individuals with type 2 diabetes (Tuso et al., 2013; Clem 2021) .

The recent (2018) Healthy Diet factsheet by WHO is almost identical with a whole food plant based diet without actually using this term. Not a single animal food is listed in the healthy food groups, and all nutrients to limit are of animal origin (WHO, 2018).

## 4. The environmental impact of food

In addition to its health benefits, the WFPB diet has a lower environmental impact. The current food system undermines the sustainability of the planet and is a huge contributor to a number of environmental problems and climate change. Livestock is responsible for much of greenhouse gas emissions, water pollution, deforestation and biodiversity loss, among others. In contrast, the production of plant foods requires fewer natural resources such as land, water, and energy and produces fewer pollution. A shift to a WFPB diet, that emphasizes the consumption of fruits, vegetables, nuts, seeds, and legumes could drastically reduce these adverse environmental effects and contribute to a more sustainable and resilient food system (Pye et al., 2022; Springmann et al., 2020).

Research has shown the benefits of switching to a plant-based diet on both health and environmental outcomes. Specifically, the plant-based dietary pattern provided nutritional adequacy and a 22% reduction in premature mortality. In addition, there was a significant reduction in pollution, with global greenhouse gas emissions decreasing by 54-87% (depending on the region), in nitrogen and phosphorus application by 23-25% and 18-21% respectively. The use of natural resources such as cropland decreased by 8-11% and the use of fresh water by 2-11% (Springmann et al., 2018).

## 4.1 The Concept of Water Footprint of food

The concept of the Water Footprint was first introduced by Professor Arjen Y. Hoekstra in 2002, in a similar spirit to the concept of the ecological footprint. It is a comprehensive indicator of freshwater use, providing both the direct use of water by consumers and producers and the indirect use of water. The water footprint of a product represents the volume of water required for its production and is measured for its entire supply chain. It provides information on the volume of water consumption by source, as well as the volume of water contamination by type of contamination.

Prior to the introduction of the water footprint concept, total water consumption and pollution was calculated as the sum of independent activities that require water, usually the domestic, agricultural and industrial sector. Such indicators did not provide information on the water needed by an economy in relation to the consumption patterns of its people. In particular, they overlooked the fact that the country of consumption of a product is very often different from the country of production, which means that the actual water consumption may be much higher than indicated by the national water withdrawals for the importing countries and lower for exporting countries. The Water Footprint indicator, being consumption-based, was able to reflect the relationship between the characteristics of the production and supply chain and the volume of water consumption and pollution required by a product or service. Therefore, water footprint makes an important contribution to understanding the crucial role of freshwater and to quantifying the impacts of consumption and trade on water use. A fuller understanding can in turn improve the management of the world's water resources in terms of sustainability from an environmental, economic and social perspective (Water Footprint Manual, 2009).

Due to its usefulness and multidimensionality, Water Footprint quickly attracted the interest of the academic community and the business world. Consequently, in 2008 Professor Arjen Y. Hoekstra founded the Water Footprint Network, with the aim of identifying and overcoming challenges related to unsustainable water use.

### *4.1.1 The Blue Water Footprint*

The blue water footprint is defined as the consumption of blue water resources, that is fresh surface or groundwater from lakes, rivers, wetlands and aquifers, along the entire supply chain of a product. In this case, consumptive use may mean that the water evaporates or is incorporated into the product, or that it does not return to the same catchment or does not return during the same period.

The water footprint in a process step is expressed as:

$$WFproc,blue = BlueWaterEvaporation + BlueWaterIncorporation + LostReturnFlow$$

Among these, the evaporation factor is considered the most important and is therefore often considered synonymous with the concept of consumptive use, but the other three should not be omitted from the calculation, provided they are present. When assessing the blue water footprint, it is most common not to consider separately the different sources of blue water, namely surface water, flowing groundwater and underground fossil water. Distinction in most cases is avoided, due to lack of data. Thus, the blue water footprint actually represents all sources as a combined total.

Consumptive water use does not imply the water disappears, as it remains within the water cycle and eventually returns to it at some point. Water is a renewable resource, however, this does not mean that its availability is unlimited. In a certain period, the amount of water recharging groundwater reserves and flowing surface water, and thus available to be used for domestic, industrial or agricultural purposes, is also certain. Thus, the blue water footprint is a measure of the amount of available water consumed in a given period. The surface and groundwater that is not consumed by humans sustains the ecosystems that depend on these flows.

#### *4.1.2 The Green Water Footprint*

The use of green water for human purposes is measured by the green water footprint. Green water is precipitation that falls on the land and remains stored in the root zone of the soil or temporarily stays on the soil or plants. It does not flow or recharge groundwater and thus eventually evaporates or is excreted as moisture by plants through the process of transpiration.

A part of the green water can be utilized for crops. But because of the part that evaporates, and due to temporal and local constraints (i.e. not all periods and areas are suitable for crop growth), not all of it can be absorbed by crops.

Therefore, the green water footprint refers to the volume of rainwater used in the production process. It is mostly associated for agricultural, horticultural and forestry products, i.e. those based on crops or wood, where it expresses the total evapotranspiration of rainwater that occurs in fields and plantations plus the water that is incorporated into the final products. Therefore, the green water footprint is calculated as follows:

$$WFproc,green = GreenWaterEvaporation + GreenWaterIncorporation$$

Distinguishing between the blue and green water footprint is important because the opportunity costs and impacts of using surface and groundwater at the hydrological, environmental and social levels are respectively very different from those of the use of rainwater.

#### *4.1.3 The Grey Water Footprint*

The idea of the grey water footprint was first introduced in 2008 by Hoekstra and Chapagain. The grey water footprint of a process step refers to the degree of freshwater pollution associated with that process step. It is an indicator of the volume of freshwater needed for the assimilation of pollutants relative to current ambient water quality standards and keep them below the maximum acceptable concentration. More specifically, the grey water footprint is calculated as the volume of water required to dilute contaminants to such an extent as to ensure that water quality is maintained above current ambient water quality standards.

Prior to the introduction of the term "grey water footprint", there was a commonly used definition of "dilution water requirement", which attempted to express the part of water consumption associated with pollution. The earlier definition may disorient some people to think that the emphasis should be on diluting pollutants rather than minimizing their emissions, which is not true.

The grey water footprint is calculated as follows:

$$WFproc,grey = \frac{L}{Cmax - Cnat}$$

Where L is the pollutant load in mass/year, Cmax is the maximum acceptable concentration of the pollutant (in mass/volume) according to the ambient water quality standard and Cnat is the natural concentration of the pollutant in the water body (in mass/volume).

Ambient water quality standards for a particular pollutant often diverge for different water bodies. The natural concentration may also diverge from place to place. Therefore, it is not surprising that the grey water footprint may present differences, greater or lesser, from one place to another.

## 4.2 Water Scarcity

In recent decades, factors such as population growth, trends in agricultural production and a general increase in living standards and consequent changes in consumption patterns have increased the water demand. The gap between water demand and availability has resulted in water scarcity. This phenomenon affects different regions of the world to varying degrees. Mekonnen and Hoekstra showed that about 4 billion people experience severe water scarcity conditions for at least 1 month of the year, with half of them living in India and China. In addition, an estimated 500 million people live in conditions of severe water scarcity for the entire year. (Mekonnen & Hoekstra, 2016).

Water is used to meet basic daily human needs. Water shortages have serious consequences for the populations they affect and create barriers to achieving health and development. Various infectious diseases associated with the consumption of unsafe water, lack of sanitation and hygiene plague much of the developing world, becoming a major cause of illness and death. The health and well-being of the most vulnerable groups, such as children and women, are most affected by water inadequacy. With their adverse impact on public health and the millions of deaths they cause, water shortages are a significant but often overlooked obstacle to economic and social prosperity in the countries they affect. (Tarrass & Benjelloun, 2012).

The UN Food and Agriculture Organization regards agriculture as "both a major cause and casualty of water scarcity" (FAO, 2019), meaning that the latter affects and is affected by the agricultural sector. Although irrigated agriculture roughly constitutes one fifth of the arable land worldwide, it supports a large part of the global population and also represents 40% of food production. The overconsumption of water resources more directly affects its major users, which are farmers. It is estimated that by 2025 over 3 billion people, or 40% of the world's population, will be dependent on irrigated water withdrawals (Vörösmarty et al., 2000). These people are particularly vulnerable to water shortages during periods of drought, which are becoming increasingly severe. Droughts threaten the survival of entire farming communities because they lead to decreased harvests and subsequent loss of income. In a global scale, the annual economic losses due to water insecurity to existing irrigators are estimated to 94 billion USD. (Sadoff et al., 2015). Given the current situation, it is estimated that by 2050, some regions of the world could experience up to a 6% decline in GDP due to the impact of water shortages on agriculture, income and health (World Bank, 2016). The industry and energy sectors account for 20% of global water consumption. Despite its smaller share compared to the primary sector, they are also affected by water scarcity. In a survey of companies from 30 countries, 84% of them stated that water is a vital resource for the operation of their production facilities.

It is estimated that the production of export commodities accounts for 22% of global water consumption and pollution. Despite their smaller share compared to the primary sector, businesses are also affected by water scarcity. In a survey that involved companies from 30 countries, 84% of them stated that water is a vital resource for the operation of their production sites.

As water, in addition to production, is used throughout the supply chain, which for most companies is spread globally, they face various types of water-related risks (Hoekstra, 2014). First, they face a natural risk, which relates both to the quantity of water, i.e. droughts or floods, and to the quality of the water, which may be polluted and unsuitable for use. Thus companies may not have the required amount of good quality water for their production and supply chain. Second, businesses may face regulatory risk, i.e. the imposition by governments of restrictions such as quality standards or pricing on water use and waste discharge. Third, in the context of today's globalized economy and information society, companies may face reputational risk, which concerns their brand and public image. Decisions and practices that affect aquatic ecosystems or local communities may influence consumption decisions. (Orr et. al., 2011).

### 4.3 The water Footprint of the Livestock Industry

In general, the production of food to sustain the earth's population requires vast water and other natural resources. In particular, however, it has been shown by multiple studies that livestock, among the multiple environmental problems it causes, has a much larger water footprint than crop production. Livestock, mostly farmed for meat, contributes significantly in the increase of water use, as it represents over 8% of global water use for human purposes.

In the period 1996-2005, the annual water footprint of animal production globally was 2,422 billion $m^3$, of which 87% is green, 6% blue and 7% grey. Each step in the supply chain of animal products has a direct water footprint, which means the consumption required at that step, and an indirect water footprint, which means the consumption at the previous steps.

In fact, the large water footprint of livestock is primarily associated with the first step of its supply chain, which is cultivation of the feed they require. Particularly, it represents 98% of the total water footprint of livestock production. It is estimated that 40% of the cereals produced globally is used for animal feed, to sustain the current food system. Also, regarding the livestock sector, other important factors in water consumption and pollution are the amounts required for drinking by the animals and the water used to maintain facilities such as farms and slaughterhouses, representing 1.1% and 0.8% respectively.

The animal products supply chain includes several processes apart from animal feed production, drinking by the animals and facilities maintenance, all of which contribute to the water footprint. However, the other processes beyond these three contribute a very small share of the total water footprint of animal products (Gerbens-Leens et al., 2013).

The water footprint of all animal products is many times greater than that of plant foods. For example, one calorie of beef requires an average of 10 liters of water, while cereals and starchy roots such as carrots and beetroot require about 0.5 liters per calorie. This makes the water footprint of red meat 20 times that of other plant-based foods. The water footprint of milk, eggs and chicken meat per gram of protein is about 30 liters and therefore 1.5 times that of pulses, which is 20 liters. (Hoekstra, 2014).

Furthermore, when comparing beef burger and cow's milk to their plant-based equivalents, soy burger and soy milk, the difference is significant. The average water footprint of 150 grams of beef burger and 1 liter of cow's milk, is 2350 and 1050 liters respectively, while the same amounts of soy burger and soy milk have a total water footprint of 158 and 297 liters respectively, for their whole supply chains (Ercin et al., 2011).

Table 2. The water footprint of selected food items

| | Litre per kilogram | Litre per kilocalorie | Litre per gram of protein | Litre per gram of fat |
|---|---|---|---|---|
| Sugar crops | 197 | 0.69 | 0.0 | 0.0 |
| Vegetables | 322 | 1.34 | 26 | 154 |
| Starchy roots | 387 | 0.47 | 31 | 226 |
| Fruits | 962 | 2.09 | 180 | 348 |
| Cereals | 1644 | 0.51 | 21 | 112 |
| Oil crops | 2364 | 0.81 | 16 | 11 |
| Pulses | 4055 | 1.19 | 19 | 180 |
| Nuts | 9063 | 3.63 | 139 | 47 |
| Milk | 1020 | 1.82 | 31 | 33 |
| Eggs | 3265 | 2.29 | 29 | 33 |
| Chicken meat | 4325 | 3.00 | 34 | 43 |
| Butter | 5553 | 0.72 | 0.0 | 6.4 |
| Pig meat | 5988 | 2.15 | 57 | 23 |
| Sheep/goat meat | 8763 | 4.25 | 63 | 54 |
| Bovine meat | 15415 | 10.19 | 112 | 153 |

*Source: Water Footprint Network*

Livestock farming exacerbates freshwater scarcity by reducing freshwater replenishment, lowering water tables and through soil compaction and drying out floodplains. It also increases runoff and worsens dry periods due to its contribution to deforestation.

In addition, the fertilizers and pesticides used for feedcrops, together with animal waste, hormones and antibiotics, sediments from eroded pastures and chemicals from tanning, are major sources of water pollution. Thus, livestock is a major factor in water pollution in a variety of ways. This extensive pollution in turn causes indirect environmental problems. In particular, it is associated with the phenomenon of eutrophication, the creation of dead zones in coastal areas, degradation of coral reefs and human health problems such as increased resistance to antibiotics, to name a few.

Regarding the water pollution aspect, in the United States alone, it is estimated that livestock are responsible for one third of nutrient pollution –mainly phosphorus and nitrogen, 50% of antibiotic use, 55% of soil and sediment erosion and 37% of pesticide use. (Steinfeld et al., 2006).

Thus, the need of the world's growing population for food, and current dietary patterns, are increasingly exacerbating the problem of water scarcity and the environmental problems caused by water pollution. Given the large difference in water footprint between plant and animal products, a dietary shift towards to plant-based options can provide a sustainable solution. From an environmental point of view, the use of natural resources is much more efficient when used to grow crops for direct human consumption than as livestock feed (Hoekstra, 2011).

A relevant study comparing the water footprint of six different types of diets estimates that the current average diet followed in the US, characterized as the least healthy option, has a water footprint of 1868 liters per capita per day. A diet that is in line with the USDA Dietary Guidelines, as well as the Mediterranean Diet, have a water footprint of 1997 and 1958 liters per capita per day, consequently increasing the water footprint by 7% and 5%, respectively. On the other hand, following a diet in accordance with the USDA Guidelines, combined with limiting daily calorie intake to2,000 kcal, is estimated to result in a 6% reduction in water footprint, with 1752 liters per capita per day. A shift to a vegetarian diet could reduce the water footprint by 20%, with 1486 liters per capita per day, while adopting a vegan diet would lead to a further reduction of 37%, with 1182 liters per capita per day (Mekonnen & Fulton, 2018).

Another study, which compares four types of diet in terms of water footprint for the European Union, finds that the current average diet in the EU - which has a very high caloric intake and also a very high consumption of animal protein relative to plant protein - has a water footprint of 4265 liters per capita per day. A diet based on the Dietary Guidelines of the German Nutrition Society would reduce the water footprint by 23%, to 3291 liters per capita per day. Adopting a vegetarian diet would reduce the water footprint by 38%, to 2655 liters per capita per day. While a combination of a diet based on the Dietary Guidelines and a vegetarian diet, i.e. replacing half of meat products with plant-based products, would result in a 30% reduction in the water footprint, to 2973 liters per capita per day (Vanham et al., 2013).

The water footprint of selected food items of Nutrients' production from various agricultural sources

| Source | Cost of Energy ($/kcal) | Cost of Protein ($/gram) |
|---|---|---|
| Corn | 0,001 | 0,02 |
| Soybeans | 0,001 | 0,012 |
| Wheat | 0,001 | 0,031 |
| Peanuts | 0,002 | 0,035 |
| Hogs | 0,008 | 0,218 |
| Cattle | 0,019 | 0,321 |
| Broilers | 0,010 | 0,115 |
| Milk | 0,016 | 0,290 |

# PART TWO: EMPIRICAL ANALYSIS

## 8. Data collection

The aim of this thesis is to investigate whether the use of more complex indicators would lead to different rankings between the four types of dietary menus. We replicated the work done by Ms. Maria-Elisabeth Bora, who used seven weekly menus for her thesis to rank 4 dietary menus according to their nutritional score. In her thesis, we used the same menus but augmented the nutrient density index to include more nutrients. The original thesis included two nutrients to encourage – Vitamin C and Fiber, and one nutrient to limit – saturated fat. We added five more nutrients to encourage- Vitamin A, Iron, Potassium, Magnesium and Zinc. We also calculated the water footprint of these diets.

We used one weekly menu which was available through the USDA at the time of the original thesis (see Appendix), which was meant to be a practical example of the USDA MyPlate plan, according to the 2015-2020 Dietary Guidelines for Americans. The USDA plan is targeted to omnivorous individuals as it contains animal products. This weekly sample menu provided seven observations (days). The modern Greek sample menus were formulated with the assistance of registered dietitians, who provided the diet plans for the purpose of the research. This type of diet is represented in our research by two weekly menus, thus 14 observations. Similarly, two vegan sample menus were used, providing us with 14 observations, which were also formulated by registered dietitians. The creation of the WFPB sample menus (14 observations), was achieved by modifying the existing vegan diet plans, with the substitution of processed foods with whole foods, which was made by my supervisor, who is a Plant Based Nutrition Professional. For more information, see the original thesis (Bora, 2020).

Therefore, a total of seven weekly sample menus are analyzed and compared, which include three meals for each day - breakfast, lunch and dinner - and also snacks. All dietary plans are aimed at healthy adult individuals, who generally have no particular nutritional needs nor need to modify their weight. In addition, recipes representative of each type of diet were used to compose the menus. The meals and recipes have been broken down into their ingredients, and each has been individually researched for their nutrients and water footprint with data mainly from USDA and FNDDS, see below

### Nutritional value/ portions databases

The data used for the dietary density part of our research were primarily derived from the USDA's Food and Nutrient Database for Dietary Studies 2017-2018. Specifically, for the servings of each food item, as well as the weight corresponding to each unit of measurement used in recipes (e.g., a teaspoon, a cup, etc.), data were drawn from the relevant FNDDS database, which we accessed and downloaded through the official USDA website in excel format. With regard to the nutrients in each food, data were drawn from the corresponding FNDDS database, which we also accessed on the USDA website. These databases were chosen for our research because due to their large size, they provide detailed data for the majority of foods. The FNDDS nutrient database presents data on the nutrient content of foods per 100 grams. However, some food items and some ingredients-mostly spices, and additionally some that we searched by trade name were not available in the FNDDS. Thus, we searched for and found data on nutrient content in the USDA National Nutrient Database for Standard Reference Legacy Release (SR Legacy), and USDA Global Branded Food Products Database (Branded Foods). In the SR Legacy and Branded Foods online databases, the option of presenting per 100 grams, 1 pound, or 4 ounces was provided. We opted to use the data per 100 grams in order to achieve homogeneity with the rest of our data.

## Water footprint databases

To compare the dietary plans on the basis of the water footprint of each, we first needed to calculate the footprint of each daily plan based on the water footprint of their ingredients. From the Water Footprint Network website, we were able to find data on the water footprint of each food. Specifically, we used two databases for this purpose. The first, contained in the "Value of Water Report: 47: The green, blue and grey water footprint of farm crops and derived crop products", presents the green, blue, and grey water footprint of crop products. There are data at national level for all countries of the world, at sub-national level for individual provinces and states, and the global average, for the period 1996-2005. The unit of measurement used is cubic meters ($m^3$) of water per ton of product (which is the same as lt per kilogram) [1]. The second water footprint database was included in the "Value of Water Report: 48: The green, blue and grey water footprint of farm animals and animal products" and similarly to the first one presents the green, blue, and grey water footprint of animal products for all countries and sub-regions of the world, for the period 1996-2005, expressed in cubic meters ($m^3$) per ton of product. This database distinguished in terms of production system, among grazing, mixed, industrial farming and also provided the weighted average.

From both databases, for our research, in spatial terms, we opted to use the global average water footprint. From the animal products database, from a production system perspective, we chose the weighted average. These options have the advantage that, on the one hand, they are more complete, with no missing data, and on the other hand, they give us information that represents the whole planet, since water can be seen as a global resource.[2]

## Recommended Daily Intake Databases

To create the NRD index, which is central to our research, it was necessary to take into account the daily recommended intakes for all the nutrients we added to the index. For Vitamin A and Iron, we obtained data from the European Food Security Authority (EFSA) website, which provides information on Dietary Reference Values for a variety of nutrients, as well as energy and water intake. It also allows for specific searches for certain population groups, such as infants, children, breastfeeding women, as well as for both genders. We focused on adult women 18-59 years old, who are characterized as premenopausal. In addition, we took into account for our research, the Population Reference Intakes (PRIs), which are the daily intakes of nutrients that cover the needs of the majority of the healthy population.

[1] As 1 $m^3$ = 1,000 lt.

[2] Of course, some regions are more water-stressed than others; to calculate the water footprint of a specific region (Greece, in our case) we would need data on food supply, percent of imports for each ingredient, origin of imports, and also the associated water footprint data for ingredients produced in Greece and imported. Notwithstanding paucity of data on country water footprints of foodstuffs, this would be below the scope of this thesis, as the calculation of environmental impacts does not constitute the core of this thesis.

For Potassium, Magnesium and Zinc, we obtained data from the Office of Dietary Supplements of the US National Institutes of Health, which is a governmental agency, as daily intakes for these nutrients were not available on the EFSA website. On the ODS website, we searched for data for health professionals and selected the Recommended Daily Allowance (RDA), which is the average daily intake adequate to meet the nutritional needs of the majority of individuals in a healthy population. Again, we focused on adult women 19-50 years old.

## Data processing

Having at our disposal appropriate and reliable data that we collected, we proceeded to check, process, and enrich the seven sample menus, which constitute the core of this research. The fact that the menus were in excel format helped us in editing and adding data required for our work.

We first performed a thorough crosscheck on the menus to ensure that they were consistent with our data. Specifically, at this stage we focused on the codes of each food item on the menus, the conversion of measurement units into grams, as well as the recipes. In the latter, both the accuracy of the ingredients and the portions corresponding to each were crosschecked.

Having established the correctness of the menus, we proceeded to add five columns to all of them, representing the nutrients we included in our research - Vitamin A, Iron, Potassium, Magnesium, and Zinc. Then, in order to facilitate obtaining data on the nutrient content of each food, we changed the order in which the five nutrients of interest are presented in the FNDDS database. Thus, by searching for each food by its code in the FNDDS database, we were able to add their contents to the sample menus. Those food items and ingredients that were not available in the FNDDS database, we retrieved in the SR Legacy or Branded Foods databases.[3]

The addition of the Vitamin A, Iron, Potassium, Magnesium, and Zinc content per 100 grams was performed in order for this amount to serve as a reference point for further calculations of the nutrient density of the seven sample menus. Specifically, using the nutrient values per 100 grams of each ingredient in combination with the used amounts of each, we created five new columns in which we calculated the nutrient content in relation to the amount of each ingredient corresponding to each meal. This procedure was relatively simple, since the previous steps had been performed correctly.

We then used the results of our nutrient content calculations, as well as the energy (kcal) per quantity of each food item used, to calculate the nutrient value per 2,000 kcal for each sample menu. This was our final aim, as the nutrient density per 2,000 kcal serves as a reference point on which we can base our statistical analysis and comparisons. Therefore, by obtaining these results we completed the data processing for the part of our research concerning the nutrient density of the four types of diets.

Focusing on to the part of our research that examines the water footprint of the USDA, Greek, Vegan, and WFPB diets, we first searched the two relevant databases (animal products and crop products) for all foods used as ingredients in the seven sample diet

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[3] Although we organized the menus and databases to facilitate this process, the fact that it was done entirely manually made it quite time-consuming. At the beginning of this thesis a request was made to the University Library to provide us with the relevant software, but our request could not be fulfilled due to lack of funds.

menus. We started by identifying the items that we considered to be the best matches to the ingredients used in the sample menus. We created a column in each menu in which we inserted the database codes and then created three columns in which we entered data for the green, blue, and gray water footprint of each food. Then, in a new column, we calculated the total water footprint by summing the three components. These data refer to the water footprint expressed in cubic meters per ton ($m^3$/ton) or liters per kilogram (lt/kg) of food. We use them as a reference point for more specific calculations.

Although the two databases offered a large amount of data from a geographical perspective, they did not provide information on certain food items, such as some processed foods or spices included in the sample menus (list is provided in the Appendix). For this reason, these foods were omitted from the water footprint part of the analysis. In addition, some foods such as peanut butter or raisins, were not present in the databases; in such cases we used the available data for their main constituents, which are peanuts and grapes respectively.

Using the water footprint data expressed in cubic meters per ton ($m^3$/ton) or liters per kilogram (lt/kg), combined with the quantities used in the menus, we calculated the water footprint of each food item, corresponding to the quantity that constitutes a portion. Then, we calculated the total water footprint of the portions, by summing the three components. Furthermore, we calculated the grey water footprint as a percentage of the total, in order to determine and highlight the percentage of the water footprint that represents water pollution.

To calculate the water footprint of each food per 2,000 kcal, we used the results of our water footprint calculations together with the energy in the amount of each food used. In this way, we found the water footprint per 2,000 kcal for all the nutrients we are analyzing. We also calculated the percentage of the grey water footprint as a percentage of the total for 2,000 kcal. These results conclude our water footprint calculations. In addition, these calculations conclude the processing of the data concerning the seven sample menus.

In the excel files of the sample menus we have added lines to sum up the amounts of each nutrient in terms of their contents per 2,000 kcal, as well as the water footprint per 2,000 kcal. We have done this for each of the three meals and snacks, which are summed again to give us the total for each day. Since each day is also an observation, we use the sums for the 49 days to create the NRD and compare the diets in terms of their water footprints.

## 9. Statistical analysis /Methodology

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 29. Data are shown at mean values for descriptive purposes. One-way analysis of variance (ANOVA) was performed to determine the differences between the four diet types.

A scatter plot diagram was used to show the relationship between Nutrient Rich Diet (NRD) and water footprint for 2,000 Kcal based on the data. A linear regression was also performed to examine the role of diet type on water footprint. The level of statistical significance chosen is 5%. Finally, it is noted that four dummy variables were created for the four diet types and used in the linear regression, with the USDA being the base (omitted) category in each case.

## 10. Results

We find that the WFPB diet contains the highest vitamin C per 2,000 cal, followed in order by the VEGAN, GREEK, and USDA diets (see Table 5). The highest Fiber per 2,000 Kcal is contained in WFPB diet followed by VEGAN, GREEK, and USDA. GREEK diet contains the highest Vitamin A in 2,0002,000 Kcal followed by VEGAN, WFPB and USDA diets. The order of Iron content in 2,0002,000 Kcal is (in descending order) VEGAN, WFPB, GREEK and USDA. The highest Potassium in 2,000 Kcal is contained in the WFPB diet followed by VEGAN, GREEK and USDA. The WFPB diet contains the highest Magnesium at 2,000 Kcal followed by VEGAN, GREEK and USDA. The highest Zinc in 2,000 Kcal is contained in the WFPB diet followed by GREEK, VEGAN and USDA. The GREEK diet contains the most fatty acids at 2,000 Kcal followed by the VEGAN, USDA and WFPB diets. The most Total fat at 2,000 Kcal is contained in the GREEK diet followed by the VEGAN, USDA, and WFPB diets. Finally, the highest water footprint at 2,000 Kcal is found in the USDA diet followed by the GREEK, WFPB and VEGAN diets with the WFPB and VEGAN diets not far apart. The results are shown in Table 1; Table 2 contains the statistical significance of the data in Table 1. The differences are statistically significant between diet groups for all nutrients except vitamin A. Among nutrients with statistically significant differences, all are statistically significant at the 1% level except for vitamin C which is significant at the 5% level.

Table 3 Nutrients and water footprint per type of diet (per 2,000 cal)

**Report**

| Type of diet | | Vitamin C | Fiber, total dietary | Vitamin A, RAE (mcg_RAE) | Iron (mg) | Potassium (mg) | Magnesium (mg) | Zinc (mg) | Fatty acids, total saturate | Total fat | WF per 2000 Kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GREEK | Mean | 227,09122034 | 35,154520130 | 1200,5758122 | 15,660659608 | 4343,7655184 | 441,94610237 | 10,318217313 | 21,403428149 | 92,630865162 | 274575,02504 |
| | N | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| | Std. Deviation | 155,09280159 | 12,182505679 | 861,64410157 | 5,2465606394 | 1196,4586911 | 143,09824860 | 2,6863013960 | 4,4858968612 | 38,252521002 | 223449,93956 |
| USDA | Mean | 104,42936753 | 18,381132688 | 669,87526920 | 7,8817359143 | 2193,4424701 | 242,56096836 | 6,2630167052 | 10,492411649 | 38,519783268 | 363502,64275 |
| | N | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| | Std. Deviation | 81,698421063 | 15,606317905 | 367,74612595 | 5,1784460595 | 1497,0683878 | 162,91191934 | 3,5501147182 | 4,8582389160 | 16,514537780 | 210590,01569 |
| VEGAN | Mean | 257,93882733 | 56,706964704 | 1082,9899387 | 22,475776142 | 4891,1791472 | 480,69955889 | 10,288240677 | 12,575283347 | 81,679858704 | 98535,061160 |
| | N | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| | Std. Deviation | 136,80718077 | 12,131614654 | 702,67051532 | 9,1609004765 | 1779,9550001 | 131,44932137 | 2,7523692821 | 3,5679423928 | 17,599566603 | 50465,195832 |
| WFPB | Mean | 289,43084590 | 68,828468663 | 930,55994440 | 22,329047894 | 5721,5884201 | 662,80387125 | 11,024875806 | 8,2975847273 | 37,301751321 | 124181,32018 |
| | N | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| | Std. Deviation | 124,79354363 | 11,900579501 | 534,95848281 | 5,4574549259 | 1017,6287173 | 132,09259389 | 2,0557395900 | 2,0529024793 | 8,7553140710 | 45811,889324 |
| Total | Mean | 236,19302210 | 48,537291383 | 1014,0180943 | 18,401814743 | 4586,6440916 | 487,63714762 | 9,9322406137 | 13,577857728 | 65,963533377 | 194012,20793 |
| | N | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| | Std. Deviation | 141,97297229 | 21,754745365 | 678,27093852 | 8,3230375697 | 1749,7379690 | 191,31153565 | 3,0196159328 | 6,3768808067 | 34,116552661 | 174607,52971 |

Table 4Nutrients and water footprint per type of diet (p-values)

| ANOVA Table | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Vitamin C * Type of diet | Between Groups | (Combined) | 168991,467 | 3 | 56330,489 | 3,174 | ,033 |
| | Within Groups | | 798512,127 | 45 | 17744,714 | | |
| | Total | | 967503,593 | 48 | | | |
| Fiber, total dietary * Type of diet | Between Groups | (Combined) | 15571,793 | 3 | 5190,598 | 32,690 | <,001 |
| | Within Groups | | 7145,116 | 45 | 158,780 | | |
| | Total | | 22716,909 | 48 | | | |
| Vitamin A, RAE (mcg_RAE) * Type of diet | Between Groups | (Combined) | 1480406,231 | 3 | 493468,744 | 1,078 | ,368 |
| | Within Groups | | 20602064,139 | 45 | 457823,648 | | |
| | Total | | 22082470,370 | 48 | | | |
| Iron (mg) * Type of diet | Between Groups | (Combined) | 1328,184 | 3 | 442,728 | 9,977 | <,001 |
| | Within Groups | | 1996,918 | 45 | 44,376 | | |
| | Total | | 3325,102 | 48 | | | |
| Potassium (mg) * Type of diet | Between Groups | (Combined) | 60249521,231 | 3 | 20083173,744 | 10,423 | <,001 |
| | Within Groups | | 86706460,850 | 45 | 1926810,241 | | |
| | Total | | 146955982,08 | 48 | | | |
| Magnesium (mg) * Type of diet | Between Groups | (Combined) | 879904,895 | 3 | 293301,632 | 15,051 | <,001 |
| | Within Groups | | 876900,081 | 45 | 19486,668 | | |
| | Total | | 1756804,976 | 48 | | | |
| Zinc (mg) * Type of diet | Between Groups | (Combined) | 114,816 | 3 | 38,272 | 5,334 | ,003 |
| | Within Groups | | 322,852 | 45 | 7,174 | | |
| | Total | | 437,668 | 48 | | | |
| Fatty acids, total saturate * Type of diet | Between Groups | (Combined) | 1328,404 | 3 | 442,801 | 31,959 | <,001 |
| | Within Groups | | 623,498 | 45 | 13,856 | | |
| | Total | | 1951,901 | 48 | | | |
| Total fat * Type of diet | Between Groups | (Combined) | 30187,177 | 3 | 10062,392 | 17,631 | <,001 |
| | Within Groups | | 25681,903 | 45 | 570,709 | | |
| | Total | | 55869,080 | 48 | | | |
| WF per 2000 Kcal * Type of diet | Between Groups | (Combined) | 4,878e11 | 3 | 1,626e11 | 7,501 | <,001 |
| | Within Groups | | 9,756e11 | 45 | 21679296825 | | |

The results of the analysis of variance showed that there were statistically significant differences between the diet types in terms of water footprint ($F = 7.501$, $p < 0.001$). The results are shown in Table 3.

Table 5. One-Way Analysis of Variance (ANOVA) of WF of 2,000 Kcal daily sample menu by type of diet.

**ANOVA**

WF per 2000 Kcal

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4,878e11 | 3 | 1,626e11 | 7,501 | <,001 |
| Within Groups | 9,756e11 | 45 | 21679296825 | | |
| Total | 1,463e12 | 48 | | | |

When examining the correlation between the variables, it was found that water footprint is negatively and statistically significantly correlated with Fiber ($p < 0.05$), Iron ($p < 0.01$), Potassium ($p < 0.05$), and Zinc ($p < 0.05$). At the same time, it is positively but not statistically significantly correlated with Vitamin A, Fatty acids, and Total fat and negatively correlated with Vitamin C and Magnesium.

The correlation test also showed that vitamin C is positively and statistically significantly correlated with Fiber ($p < 0.01$), Iron ($p < 0.05$), Potassium ($p < 0.01$), Magnesium ($p < 0.01$) and Zinc ($p < 0.05$). At the same time, it is positively but statistically not significantly correlated with vitamin A and Total fat and negatively correlated with Fatty acids.

The results also showed that Fiber is positively and statistically significantly correlated with Iron, Potassium, Magnesium, and Zinc ($p < 0.01$) and negatively correlated with Fatty acids ($p < 0.05$). At the same time, it is positively but not statistically significantly correlated with Vitamin A and negatively correlated with Total fat.

At the same time, vitamin A was shown to be positively and statistically significantly correlated with Iron, Potassium, Magnesium and Zinc ($p < 0.01$). At the same time, it is also positively but statistically non-significantly correlated with Fatty acids and Total fat.

The results also showed that Iron is positively and statistically significantly correlated with Potassium, Magnesium, and Zinc ($p < 0.01$). It is also negatively but statistically non-significantly correlated with Fatty acids and positively correlated with Total fat.

At the same time, Potassium is positively and statistically significantly correlated with Magnesium and Zinc ($p < 0.01$). At the same time, it is negatively but statistically non-significantly correlated with Fatty acids and Total fat.

Finally, it was observed that Magnesium is positively and statistically significantly correlated with Zinc ($p < 0.01$) and negatively but not statistically significantly correlated with Fatty acids and Total fat. A positive, but statistically non-significant correlation exists between Zinc and Fatty acids and Total fat, while Fatty acids are positively and statistically significantly correlated with Total fat ($p < 0.01$).

Table 6 Correlation matrix between selected nutrients and WF of diets.

| | WF per 2000 Kcal | Vitamin C | Fiber, total dietary | Vitamin A, RAE (mcg_RAE) | Iron (mg) | Potassium (mg) | Magnesium (mg) | Zinc (mg) | Fatty acids, total saturate | Total fat |
|---|---|---|---|---|---|---|---|---|---|---|
| WF per 2000 Kcal | | | | | | | | | | |
| Vitamin C | -0,002 | | | | | | | | | |
| Fiber, total dietary | -,347* | ,554** | | | | | | | | |
| Vitamin A, RAE (mcg_RAE) | 0,028 | 0,182 | 0,254 | | | | | | | |
| Iron (mg) | -,375** | ,308* | ,733** | ,585** | | | | | | |
| Potassium (mg) | -,290* | ,568** | ,764** | ,505** | ,653** | | | | | |
| Magnesium (mg) | -0,222 | ,475** | ,843** | ,492** | ,772** | ,873** | | | | |
| Zinc (mg) | -,355* | ,288* | ,619** | ,446** | ,734** | ,680** | ,732** | | | |
| Fatty acids, total saturate | 0,183 | -0,032 | -,348* | 0,156 | -0,199 | -0,126 | -0,193 | 0,128 | | |
| Total fat | 0,025 | 0,030 | -0,122 | 0,118 | 0,009 | -0,013 | -0,115 | 0,130 | ,797** | |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

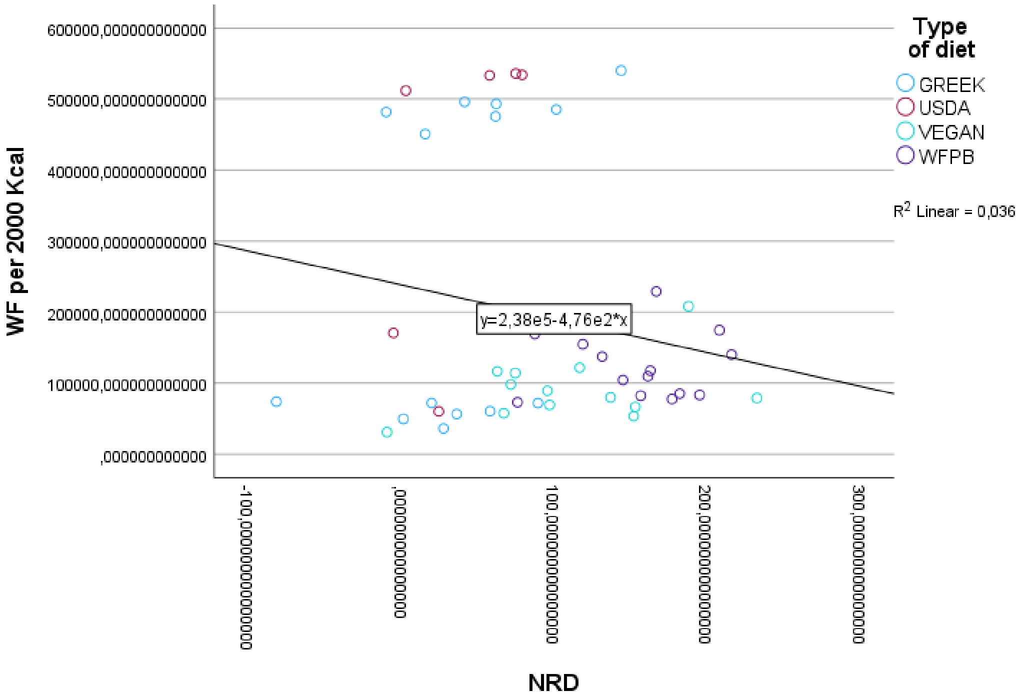
The water footprint per 2,000 Kcal is negatively but not statistically significantly correlated with the NRD index ($r = –0.189$, $p = 0.19$). The correlation between the water footprint and the NRD index according to diet type is shown in Figure 1.

Table 7 Correlation matrix between NRD index and WF of diets.

**Correlations**

| | | NRD | WF per 2000 Kcal |
|---|---|---|---|
| NRD | Pearson Correlation | 1 | -,189 |
| | Sig. (2-tailed) | | ,193 |
| | N | 49 | 49 |
| WF per 2000 Kcal | Pearson Correlation | -,189 | 1 |
| | Sig. (2-tailed) | ,193 | |
| | N | 49 | 49 |

Figure 6. The Nutrient Rich Diet (NRD) index plotted against WF per 2,000 kcal daily menu. Data are means for the four types of diet (sample menus).




Linear regression showed that diet type was a significant factor in shaping the water footprint ($F = 7.501$, $p < 0.001$). To perform the regression, four dummy variables were created for the four diet types. The regression constant is the mean value of the water footprint in 2,000 Kcal for the USDA diet.

The coefficients of the other diet types indicate whether the mean values of the water footprint are larger or smaller than the water footprint of the USDA diet.

The empirical findings show that the highest average water footprint at 2,000 Kcal is found in the USDA diet ($\beta = 363{,}502.64$, $t = 6.532$, $p < 0.001$). The average water footprint in 2,000 Kcal for the GREEK diet is lower by 88,927.62 compared to the USDA diet ($t = -1.305$, $p = 0.199$). The average water footprint in 2,000 Kcal for the WFPB diet is lower by 239,321.32 compared to the USDA diet ($t = -3.511$, $p = 0.001$).

Finally, the average water footprint in 2,000 Kcal for the VEGAN diet is smaller by 264,967.58 compared to the USDA diet ($t = -3.888$, $p < 0.001$).

Table 8. ANOVA results for Type of Diet predicting WF

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 4,878e11 | 3 | 1,626e11 | 7,501 | <,001[b] |
| | Residual | 9,756e11 | 45 | 21679296825 | | |
| | Total | 1,463e12 | 48 | | | |

a. Dependent Variable: WF per 2000 Kcal

b. Predictors: (Constant), WFPB, VEGAN, GREEK

Table 9. Regression analysis summary (for Type of Diet predicting WF)

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 363502,643 | 55651,077 | | 6,532 | <,001 |
| | GREEK | -88927,618 | 68158,371 | -,232 | -1,305 | ,199 |
| | VEGAN | -264967,582 | 68158,371 | -,693 | -3,888 | <,001 |
| | WFPB | -239321,323 | 68158,371 | -,626 | -3,511 | ,001 |

a. Dependent Variable: WF per 2000 Kcal

The highest NRD value was found in the WFPB diet followed in order by the VEGAN, GREEK and USDA diets. At the same time, it was proved that the differences between the four types of diets for the NRD index were statistically significant ($F = 14.986$, $p < 0.001$).

Table 10. Mean values of NRD indices per type of diet.

**Report**

NRD

| Type of diet | Mean | N | Std. Deviation |
|---|---|---|---|
| GREEK | 40,450745743 | 14 | 54,218145027 |
| USDA | 42,585819872 | 7 | 34,742314366 |
| VEGAN | 108,57500241 | 14 | 60,539358109 |
| WFPB | 155,98500116 | 14 | 41,503536316 |
| Total | 93,229616928 | 49 | 69,354083504 |

Table 11 Significance of differences according to NRD index per type of diet

**ANOVA Table**

| | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| NRD * Type of diet | Between Groups | (Combined) | 115384,156 | 3 | 38461,385 | 14,986 | <,001 |
| | Within Groups | | 115495,311 | 45 | 2566,562 | | |
| | Total | | 230879,467 | 48 | | | |

## Evaluation of diets/ Methods

To achieve the aim of this thesis, which is to determine whether the four different diet types would score differently in terms of their nutrient density by adding more nutrients to the analysis, and therefore whether we need more complex indicators to assess nutrient density, we used an enriched NRD indicator. This index is based on the NRF index family. It consists of 7 nutrients to encourage (Vitamin C, Fiber, Vitamin A, Iron, Potassium, Magnesium, and Zinc), whereas in Bora (2020), it consisted of 2 (Vitamin C and Fiber). We used only 1 nutrient to limit (saturated fat), as is Bora (2020).

Then, we used the NR7 subscore (instead of the NR2 subscore), which measures the nutritional adequacy of the seven sample menus in the seven nutrients correlated with health-promoting factors, and the LIM subscore, which measures saturated fat.

Subsequently, to show the water footprint of each type of diet, we created the WF/NRD point ratio, which shows the water footprint in respect to nutrient density per 2,000 kcal (i.e. it shows the water footprint required to produce one point in the NR7 index).

Table 1 shows the nutrients used in the calculation of the 7NR7 (Nutrient Rich subscore), the LIM (limiting nutrients subscore), the NRD (Nutrient Rich Diet index), and their Recommended Daily values for healthy adults, based on a 2,000-kcal/day diet.

Table 12 Reference Daily Values for nutrients, based on 2,000 kcal/day diet for adults

| Nutrient | DV | MRV |
|---|---|---|
| Vitamin C (mg) | 110 mg | |
| Fiber (g) | 25 g | |
| Vitamni A (mcg_RAE) | 650 mcg | |
| Iron (mg) | 16 mg | |
| Potassium (mg) | 2600 mg | |
| Magnesium (mg) | 310 mg | |
| Zinc (mg) | 8 mg | |
| Saturated fat (g) | | 44 g |

*Note: DV = ??; MRV = ??*

The NR7 subscore is the mean of percent daily values of seven nutrients to encourage (Vitamin C, Fiber, Vitamin A, Iron, Potassium, Magnesium and Zinc), as provided by a 2,000 kcal/day diet. The LIM subscore is the percent daily value of the nutrient to limit (saturated fat), as provided by a 2,000 kcal/day diet. The NRD Index is the sum of positive NR7 and negative LIM subscores.

The WF/NRD point ratio is the mean of the total Water Footprint per NRD point and is calculated as follows:

WF/NRD point ratio = WF per 2,000kcal / NRD

Table 2 shows the algorithms used for the calculation of NR2, LIM, and NRD index.

Table 13 Algorithms for the Nutrient Rich (NR7) and Limiting Nutrient (LIM) subscores and for the composite NRD Index Score Calculated per 2,000 kcal of diet

| Model | Algorithm | Reference amount | Notes |
|---|---|---|---|
| NR7 subscore | $\sum$(Nutient$_i$ per 2,000 Kcal / Dv$_i$) * 100 / 7 | 2,000 kcal | Nutrient$_i$ = The content of nutrient in a 2,000 kcal/ day sample menu of diet<br>$_i$ = 7 (Vitamin C, Fiber, Vitamin A, Iron, Potassium, Magnesium, Zinc)<br>Dv$_i$ = Daily Recommended Value for Nutienti |
| LIM subscore | LIM = L$_i$ /MRV$_i$) * 100 | 2,000 kcal | L$_i$ = The content of nutrient in a 2,000 kcal/day sample menu of diet<br>$_i$ = 1 (Saturated fat)<br>MRV$_i$ = Maximum Recommended Value for Nutient$_i$ |
| NRD index | NRD = NR7 - LIM | 2,000 kcal | Combination of positive NR7 and negative LIM |

## 11. Discussion and Concluding remarks

Emerging evidence support that reducing the consumption of meat and other animal products and adopting a plant-based diet instead, can significantly improve health outcomes and at the same time contribute to reducing the environmental impact of the current food system (Pye et al., 2022). Consumption of meat, particularly certain forms of meat such as red and processed meat, has been shown to contribute to increased obesity and a host of chronic diseases. For this reason, major health organizations consistently recommend drastic limitation in their consumption (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020; WHO IARC, 2015). In addition, reducing or eliminating meat from the diet can reduce ongoing environmental issues such as the depletion of natural resources, greenhouse gas emissions, loss of biodiversity, and the emergence and spread of zoonotic diseases (The Lancet Infectious Diseases, 2022; Poore & Nemecek, 2018; Marlow et al., 2009). In particular, as we have examined, such a change in eating habits has a major impact on the sustainable use of water resources and aquatic ecosystems.

The aim of this study was to evaluate and rank four different types of diet in term of their nutrient density in order to examine their health and environmental benefits, and also to compare our results with a previous thesis, in order to test whether the use of composite indices would lead to different results on the nutrient density of the same four different diets.

The main results of the analysis showed that the diet with the highest nutrient density score was the WFPB diet. The second most nutritionally adequate diet was the Vegan diet, followed by the USDA and Greek diet. Vegan diet is the most sustainable among the four, with the lowest water footprint, followed by the WFPB diet. The Greek diet had a higher score and the USDA diet was shown to have the greatest water footprint.

The results of this thesis are in agreement with the literature we studied, as well as with previous thesis. The most important finding of this study is that using complex indices and models to evaluate the nutritional quality of dietary patterns is not necessary, as certain nutrients have strong correlation with nutrient density. Identifying the key nutrients that indicate the nutritional adequacy of foods and diets can lead to constructing simple indices that provide with accurate results.

The importance of this research lies within the necessity of promoting public health in combination with environmental sustainability. As chronic diseases and obesity are increasing enormously in all regions of the world, and climate change and its associated environmental problems are more topical and threatening than ever before, our findings are essential. Existing literature points to the need for a large- scale shift towards plant-based diets, as it is shown that they can contribute to addressing public health and environmental protection issues.

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## Appendix

Table A1. Vitamin C (mg) per 2,000 kcal by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 172.6641 | 77.48729 | 29.28744 | 87.81 | 292.44 |
| GREEK | 14 | 227.0912 | 155.09280 | 41.45029 | 54.57 | 600.69 |
| VEGAN | 14 | 257.2175 | 140.51250 | 37.55355 | 21.58 | 490.64 |
| WFPB | 14 | 281.9620 | 121.71677 | 32.53017 | 136.43 | 484.87 |
| Total | 49 | 243.6008 | 133.87076 | 19.12439 | 21.58 | 600.69 |

Graph A1. Vitamin C (mg) per 2,000 kcal by type of diet

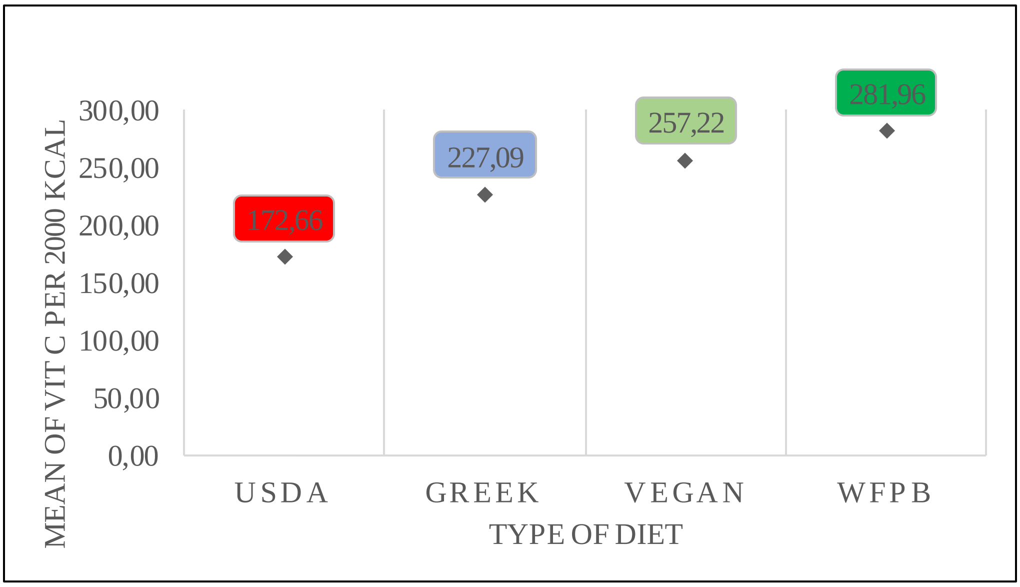


Table A2. Fiber (g) per 2,000 kcal by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| USDA | 7 | 28.3235 | 9.85473 | 3.72474 | 20.47 | 48.86 |
| GREEK | 14 | 35.1545 | 12.18251 | 3.25591 | 18.80 | 56.41 |
| VEGAN | 14 | 57.4168 | 11.74907 | 3.14007 | 22.58 | 72.59 |
| WFPB | 14 | 68.8723 | 12.34188 | 3.29851 | 37.14 | 85.96 |
| Total | 49 | 50.1730 | 19.58756 | 2.79822 | 18.80 | 85.96 |

Graph A2. Fiber (g) per 2,000 kcal by type of diet


Table A3. Saturated (g) per 2,000 kcal by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 18.3601 | 2.98457 | 1.12806 | 13.89 | 22.47 |
| GREEK | 14 | 22.4322 | 5.35681 | 1.43167 | 13.90 | 32.99 |
| VEGAN | 14 | 13.7815 | 5.85889 | 1.56585 | 7.25 | 30.35 |
| WFPB | 14 | 8.4090 | 1.71720 | .45894 | 6.14 | 13.07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total | 49 | 15.3722 | 7.04980 | 1.00711 | 6.14 | 32.99 |

Graph A3. Saturated (g) per 2,000 kcal by type of diet

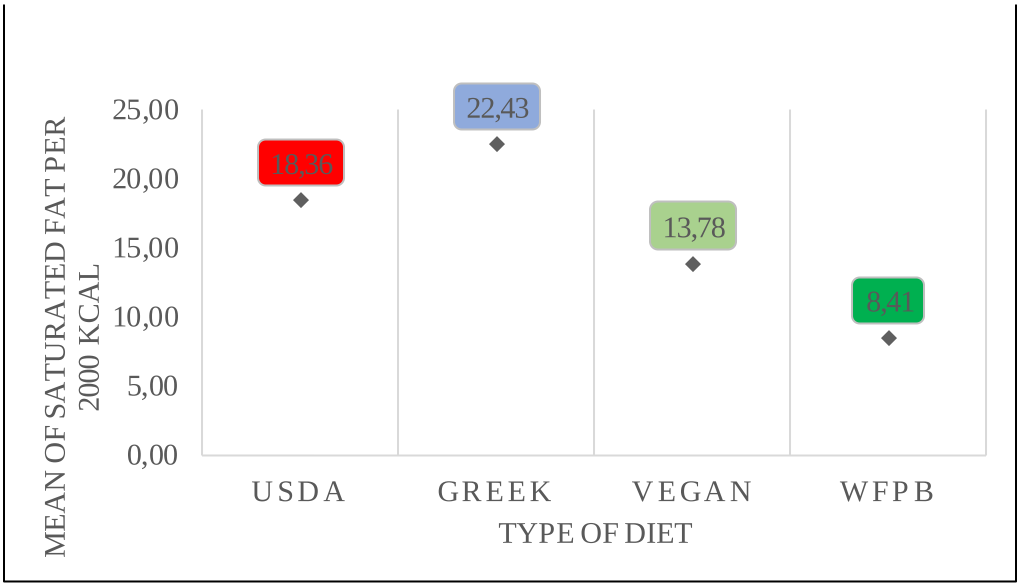


Table A4. Total fat (g) per 2,000 kcal by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 68.4353 | 10.48191 | 3.96179 | 53.01 | 79.41 |
| GREEK | 14 | 92.6309 | 38.25252 | 10.22342 | 48.33 | 213.19 |
| VEGAN | 14 | 80.7218 | 16.66315 | 4.45341 | 58.87 | 103.23 |
| WFPB | 14 | 37.9438 | 6.98967 | 1.86807 | 28.64 | 54.31 |
| Total | 49 | 70.1469 | 31.32768 | 4.47538 | 28.64 | 213.19 |

Graph A4. Total fat (g) per 2,000 kcal by type of diet

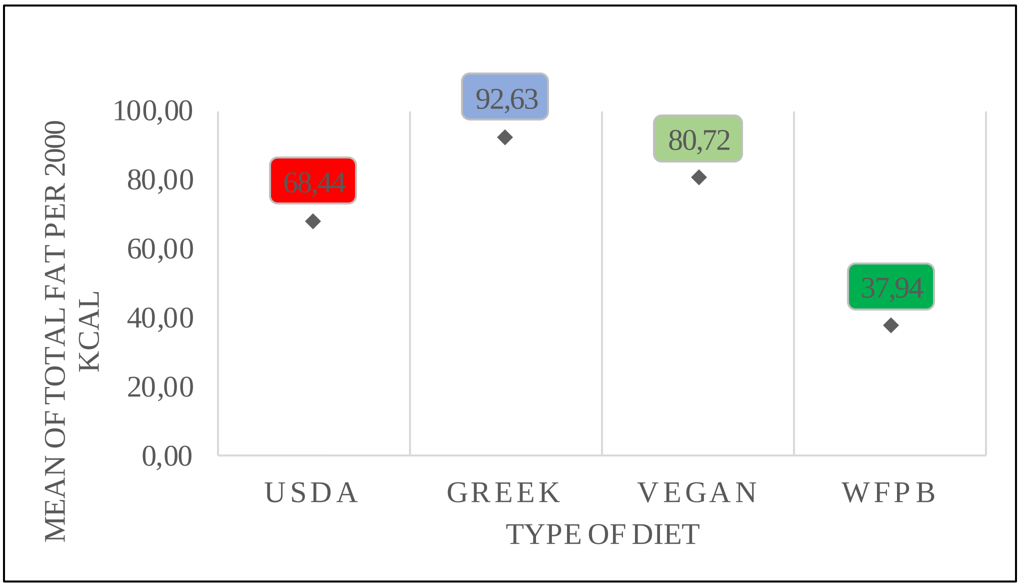


Table A5. Cost (EUR) per 2,000 kcal by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 6.6518 | 1.71558 | .64843 | 3.97 | 9.50 |
| GREEK | 14 | 5.6512 | 1.20935 | .32321 | 3.57 | 7.90 |
| VEGAN | 14 | 5.1876 | 1.45533 | .38895 | 2.98 | 8.27 |
| WFPB | 14 | 3.8687 | .80503 | .21515 | 2.59 | 5.33 |
| Total | 49 | 5.1524 | 1.54744 | .22106 | 2.59 | 9.50 |

Graph A5. Cost (EUR) per 2,000 kcal by type of diet

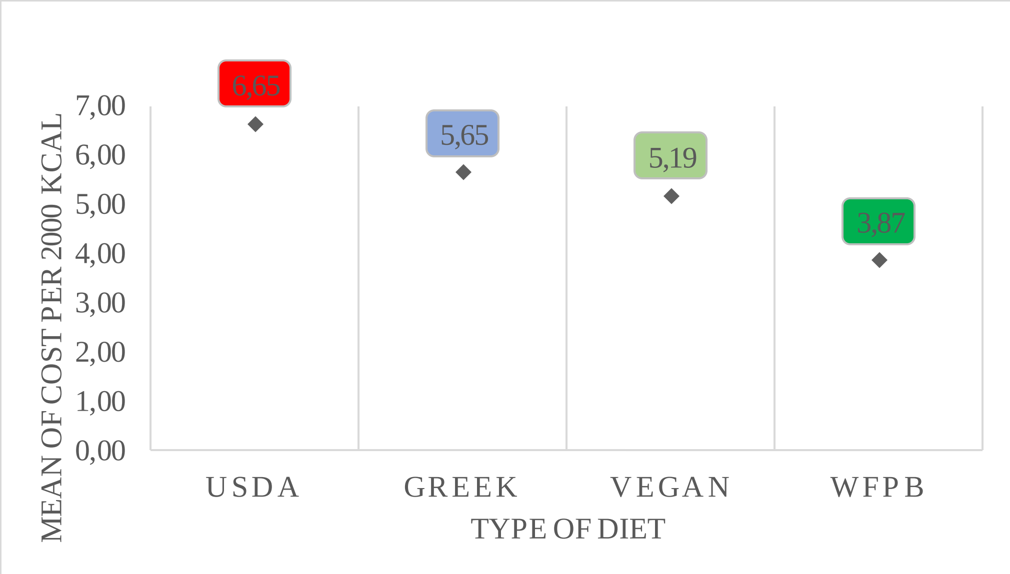


Table A6. NR2 per type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 135.1307 | 44.22629 | 16.71597 | 87.47 | 194.33 |
| GREEK | 14 | 173.5323 | 83.66145 | 22.35946 | 62.41 | 342.36 |
| VEGAN | 14 | 231.7507 | 78.04591 | 20.85865 | 54.97 | 342.04 |
| WFPB | 14 | 265.9092 | 69.19321 | 18.49266 | 149.28 | 389.85 |
| Total | 49 | 211.0736 | 85.67576 | 12.23939 | 54.97 | 389.85 |

Graph A6. NR2 per type of diet

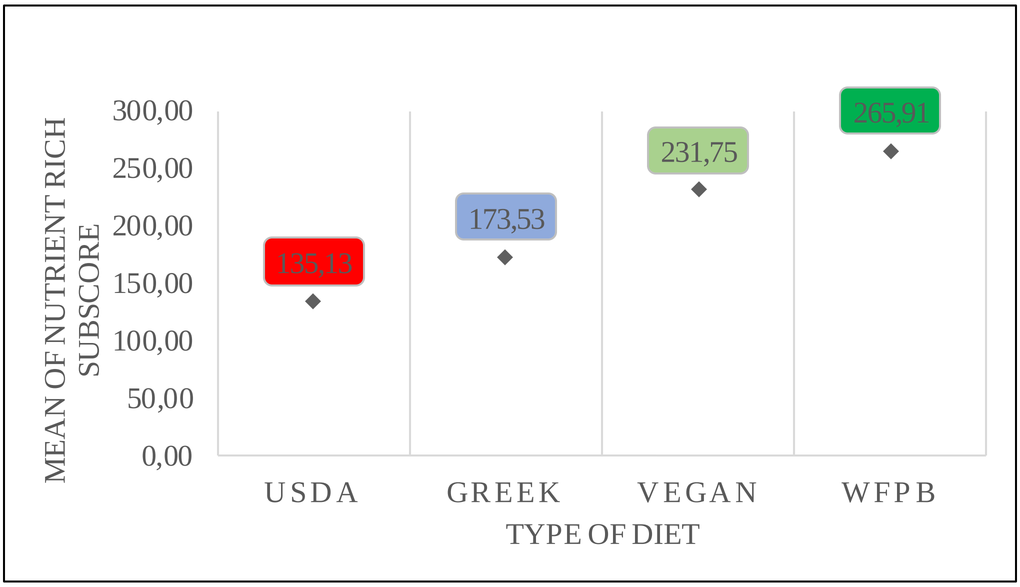


Table A7. LIM per type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 91.8003 | 14.92283 | 5.64030 | 69.43 | 112.37 |
| GREEK | 14 | 112.1608 | 26.78407 | 7.15834 | 69.50 | 164.94 |
| VEGAN | 14 | 68.9077 | 29.29443 | 7.82927 | 36.24 | 151.77 |
| WFPB | 14 | 42.0452 | 8.58598 | 2.29470 | 30.68 | 65.37 |
| Total | 49 | 76.8611 | 35.24898 | 5.03557 | 30.68 | 164.94 |

Graph A7. LIM per type of diet

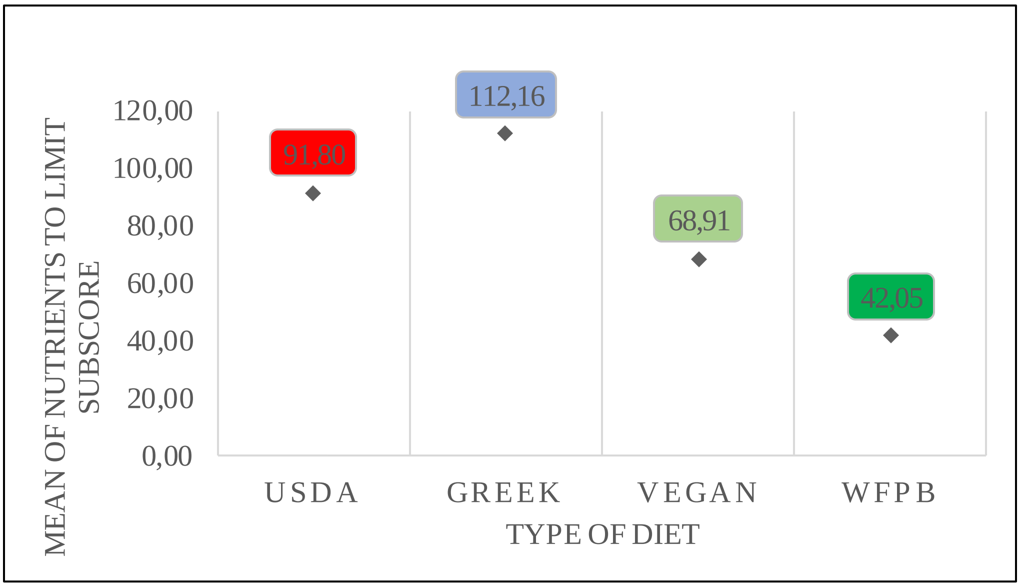


Table A8. NRD Index by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 43.3304 | 57.48420 | 21.72699 | −24.90 | 110.79 |
| GREEK | 14 | 61.3715 | 92.18416 | 24.63725 | −102.53 | 222.86 |
| VEGAN | 14 | 162.8430 | 77.37844 | 20.68026 | −26.65 | 251.08 |
| WFPB | 14 | 223.8640 | 71.04239 | 18.98688 | 102.57 | 353.98 |
| Total | 49 | 134.2125 | 105.06396 | 15.00914 | −102.53 | 353.98 |

Graph A8. NRD Index by type of diet

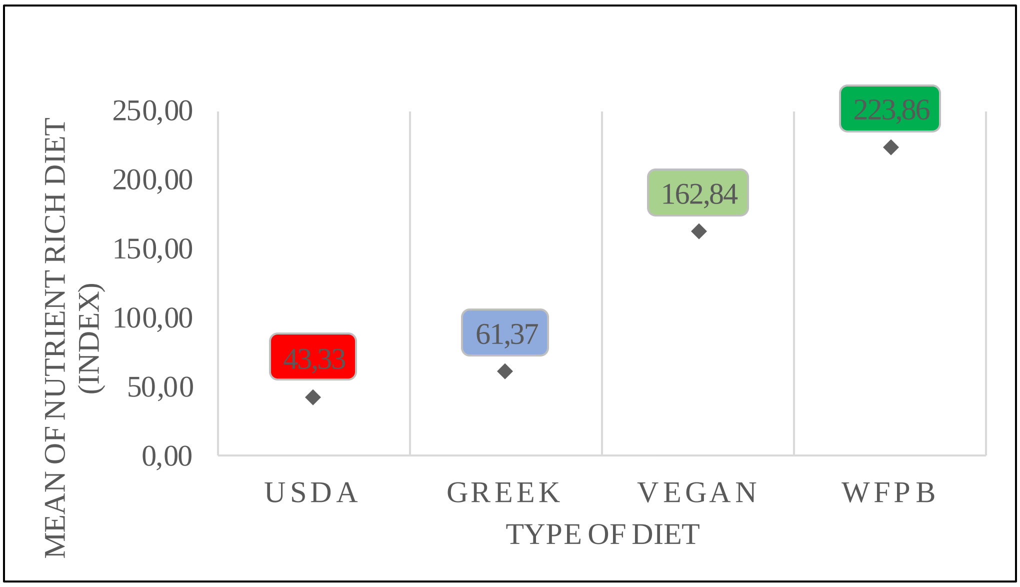


Table A9. N/P ratio by type of diet

| | N | Mean | Std. Deviation | Std. Error | Minimum | Maximum |
|---|---|---|---|---|---|---|
| USDA | 7 | 7.9270 | 11.35099 | 4.29027 | -4.23 | 27.86 |
| GREEK | 14 | 10.3290 | 15.52055 | 4.14804 | -20.95 | 34.00 |
| VEGAN | 14 | 32.8205 | 19.94033 | 5.32928 | -6.87 | 82.51 |
| WFPB | 14 | 60.0027 | 21.49859 | 5.74574 | 31.64 | 90.67 |
| Total | 49 | 30.6045 | 27.61552 | 3.94507 | -20.95 | 90.67 |

Graph A9. N/P ratio by type of diet

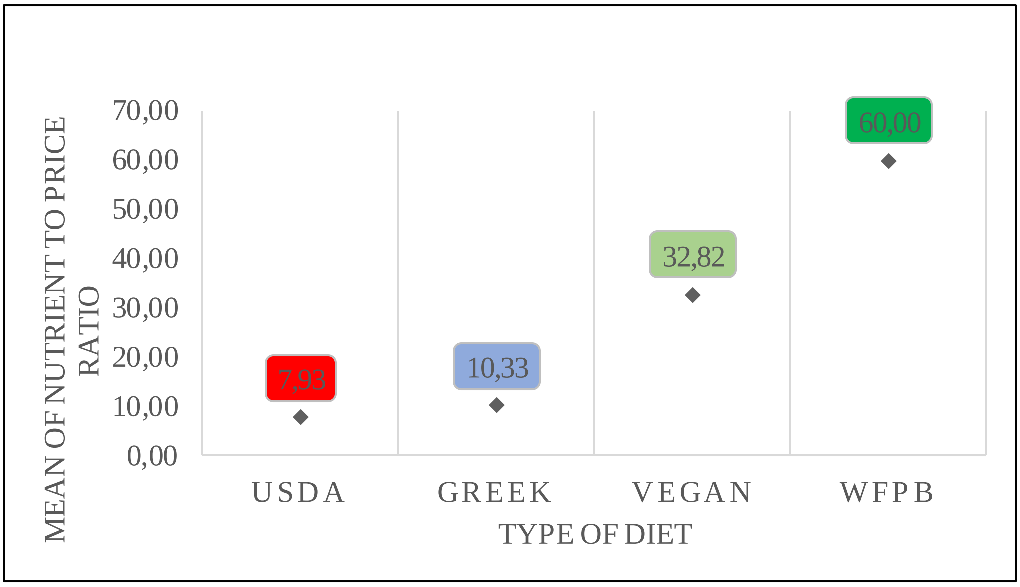


Table A10. One-Way Analysis of Variance (ANOVA) of Cost of 2,000 Kcal daily sample menu by type of diet

| Source | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Between Groups | 3 | 42.309 | 14.103 | 8.738 | .000 |
| Within Groups | 45 | 72.631 | 1.614 | | |
| Total | 48 | 114.940 | | | |

Table A11. Multiple comparison analysis (Tukey' s post-hoc tests) of types of diets by their cost per 2,000Kcal

Dependent Variable: Cost per 2,000 Kcal

| | Std. Error | Sig. | 95% Confidence Interval |
|---|---|---|---|

| (I) Type of Diet | (J) Type of Diet | Mean Difference (I-J) | | | Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| USDA | GREEK | 1.00058 | .58810 | .335 | -.5683 | 2.5694 |
| | VEGAN | 1.46420 | .58810 | .075 | -.1047 | 3.0331 |
| | WFPB | 2.78311* | .58810 | .000 | 1.2142 | 4.3520 |
| GREEK | USDA | -1.00058 | .58810 | .335 | -2.5694 | .5683 |
| | VEGAN | .46362 | .48018 | .770 | -.8174 | 1.7446 |
| | WFPB | 1.78253* | .48018 | .003 | .5016 | 3.0635 |
| VEGAN | USDA | -1.46420 | .58810 | .075 | -3.0331 | .1047 |
| | GREEK | -.46362 | .48018 | .770 | -1.7446 | .8174 |
| | WFPB | 1.31891* | .48018 | .041 | .0379 | 2.5999 |
| WFPB | USDA | -2.78311* | .58810 | .000 | -4.3520 | -1.2142 |
| | GREEK | -1.78253* | .48018 | .003 | -3.0635 | -.5016 |
| | VEGAN | -1.31891* | .48018 | .041 | -2.5999 | -.0379 |

*. The mean difference is significant at the 0.05 level.

Table A12. Correlation matrix between selected nutriens and cost of diets

| | | Vit C per 2,000 Kcal | Fiber per 2,000 Kcal | Saturated fat per 2,000 Kcal | Total fat per 2,000 Kcal |
|---|---|---|---|---|---|
| Fiber per 2,000 Kcal | Pearson Correlation | .441** | | | |
| | Sig. (2-tailed) | .002 | | | |
| | N | 49 | | | |
| Saturated fat per 2,000 Kcal | Pearson Correlation | -.146 | -.662** | - | |
| | Sig. (2-tailed) | .317 | .000 | | |

| | | | | | |
|---|---|---|---|---|---|
| | N | 49 | 49 | | |
| Total fat per 2,000 Kcal | Pearson Correlation | -.122 | -.395** | .675** | - |
| | Sig. (2-tailed) | .405 | .005 | .000 | |
| | N | 49 | 49 | 49 | |
| Cost per 2,000 Kcal | Pearson Correlation | -.097 | -.323* | .361* | .361* |
| | Sig. (2-tailed) | .505 | .024 | .011 | .011 |
| | N | 49 | 49 | 49 | 49 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table A13. Correlation matrix between NRD index and Cost per 2,000 Kcal

| | | Cost per 2,000 Kcal | Nutrient Rich Diet (Index) |
|---|---|---|---|
| Cost per 2,000 Kcal | Pearson Correlation | 1 | -.298* |
| | Sig. (2-tailed) | | .038 |
| | N | 49 | 49 |
| Nutrient Rich Diet (Index) | Pearson Correlation | -.298* | 1 |
| | Sig. (2-tailed) | .038 | |
| | N | 49 | 49 |

*. Correlation is significant at the 0.05 level (2-tailed).

Table A14. One-Way Analysis of Variance (ANOVA) of Nutrient Rich Diet score by type of diet

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Between Groups | 256097.635 | 3 | 85365.878 | 14.033 | .000 |
| Within Groups | 273747.310 | 45 | 6083.274 | | |
| Total | 529844.945 | 48 | | | |

Table A15. Multiple comparison analysis (Tukey' s post-hoc tests) of types of diets by their NRD score

Dependent Variable: Nutrient Rich Diet

| (I) Type of Diet | (J) Type of Diet | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| USDA | GREEK | -18.04113 | 36.10483 | .959 | -114.3580 | 78.2757 |
| | VEGAN | -119.51258* | 36.10483 | .010 | -215.8294 | -23.1957 |
| | WFPB | -180.53364* | 36.10483 | .000 | -276.8505 | -84.2168 |
| GREEK | USDA | 18.04113 | 36.10483 | .959 | -78.2757 | 114.3580 |
| | VEGAN | -101.47145* | 29.47947 | .007 | -180.1138 | -22.8291 |
| | WFPB | -162.49251* | 29.47947 | .000 | -241.1349 | -83.8501 |
| VEGAN | USDA | 119.51258* | 36.10483 | .010 | 23.1957 | 215.8294 |
| | GREEK | 101.47145* | 29.47947 | .007 | 22.8291 | 180.1138 |
| | WFPB | -61.02106 | 29.47947 | .179 | -139.6634 | 17.6213 |
| WFPB | USDA | 180.53364* | 36.10483 | .000 | 84.2168 | 276.8505 |
| | GREEK | 162.49251* | 29.47947 | .000 | 83.8501 | 241.1349 |
| | VEGAN | 61.02106 | 29.47947 | .179 | -17.6213 | 139.6634 |

*. The mean difference is significant at the 0.05 level.

Table A16. One-Way Analysis of Variance (ANOVA) of Nutrient to Price ratio by type of diet

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 21523.515 | 3 | 7174.505 | 21.406 | .000 |
| Within Groups | 15082.088 | 45 | 335.158 | | |
| Total | 36605.603 | 48 | | | |

Table A17. Multiple comparison analysis (Tukey' s post-hoc tests) of types of diets by their nutrient to price ratio

Dependent Variable: Nutrient to Price ratio

| (I) Type of Diet | (J) Type of Diet | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| USDA | GREEK | -2.40196 | 8.47464 | .778 | -19.4708 | 14.6668 |
| | VEGAN | -24.89346* | 8.47464 | .005 | -41.9623 | -7.8247 |
| | WFPB | -52.07566* | 8.47464 | .000 | -69.1444 | -35.0069 |
| GREEK | USDA | 2.40196 | 8.47464 | .778 | -14.6668 | 19.4708 |
| | VEGAN | -22.49150* | 6.91951 | .002 | -36.4281 | -8.5549 |
| | WFPB | -49.67369* | 6.91951 | .000 | -63.6103 | -35.7371 |
| VEGAN | USDA | 24.89346* | 8.47464 | .005 | 7.8247 | 41.9623 |
| | GREEK | 22.49150* | 6.91951 | .002 | 8.5549 | 36.4281 |
| | WFPB | -27.18219* | 6.91951 | .000 | -41.1188 | -13.2456 |
| WFPB | USDA | 52.07566* | 8.47464 | .000 | 35.0069 | 69.1444 |
| | GREEK | 49.67369* | 6.91951 | .000 | 35.7371 | 63.6103 |
| | VEGAN | 27.18219* | 6.91951 | .000 | 13.2456 | 41.1188 |

*. The mean difference is significant at the 0.05 level.

Table A18. ANOVA results for Type of Diet predicting Cost

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 40.599 | 1 | 40.599 | 25.667 | .000[b] |
| | Residual | 74.341 | 47 | 1.582 | | |
| | Total | 114.940 | 48 | | | |

a. Dependent Variable: Cost per 2,000 Kcal

b. Predictors: (Constant), Type of Diet

Table A19. Regression analysis summary (for Type of Diet predicting Cost)

**Coefficients[a]**

| | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| Model | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 7.551 | .506 | | 14.912 | .000 |
| | Type of Diet | -.884 | .174 | -.594 | -5.066 | .000 |

a. Dependent Variable: Cost per 2,000 Kcal

Table A20. Correlation between vitamin C and other nutrients of importance (data includes all food groups)

| | | Vitamin C (mg) |
|---|---|---|
| Fiber, total dietary (g) | Pearson Correlation | .104** |

| | | |
|---|---|---|
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Vitamin A, RAE (mcg_RAE) | Pearson Correlation | .147** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Vitamin E (alpha-tocopherol) (mg) | Pearson Correlation | .110** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Calcium (mg) | Pearson Correlation | .097** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Magnesium (mg) | Pearson Correlation | .062** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Iron (mg) | Pearson Correlation | .155** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Zinc (mg) | Pearson Correlation | .057** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Potassium (mg) | Pearson Correlation | .120** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Fatty acids, total saturated (g) | Pearson Correlation | -.130** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |

| | | |
|---|---|---|
| Total Fat (g) | Pearson Correlation | -.135** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Cholesterol (mg) | Pearson Correlation | -.100** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Sodium (mg) | Pearson Correlation | -.109** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |
| Sugars, total (g) | Pearson Correlation | .090** |
| | Sig. (2-tailed) | .000 |
| | N | 7083 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table A21. Water footprint of foods: Correspondence table

| *FOOD ITEM* | *USDA CODE* | *WFN CODE* |
|---|---|---|
| *Oatmeal cooked* | *56203056* | *110422* |
| *Peanut butter* | *42202000* | *080290* |
| *Raisins* | *62125100* | *080620* |
| *Orange juice, 100%, freshly squeezed* | *61210010* | *200911* |
| *Tortilla, flour* | *52215200* | *110100* |
| *Tuna, canned, water pack* | *26155190* | |
| *Mayonnaise, regular* | *83107000* | |
| *Cucumber, raw* | *75111000* | *070700* |

| | | |
|---|---|---|
| *Yogurt, Greek, vanilla, lowfat* | *(SR Legacy) 170907* | *040310* |
| *Milk, reduced fat* | *11112110* | *040120* |
| *chicken* | *24107080* | *010599* |
| *olive oil* | *82104000* | *150910* |
| *flour (all purposes)* | *(SR LEGACY) 169761* | *110100* |
| *honey* | *91302010* | |
| *Lemon juice freshly squeezed* | *61113010* | *080530* |
| *salt* | *(SR LEGACY) 173468* | |
| *Rice Pilaf* | *58162310* | *100630* |
| *Green peas, frozen, cooked, no added fat* | *75224022* | *071021* |
| *Corn, frozen, cooked, no added fat* | *75216112* | *071040* |
| *Margarine, tub* | *81102020* | *151219* |
| *Cookie, chocolate* | *53207000* | |
| *Carrots, raw* | *73101010* | *070610* |
| *Hummus, plain* | *41205070* | *071320* |
| *Crackers, wheat, reduced fat* | *54338100* | |
| *toasted oat cereal* | *57306700* | *110412* |
| *banana, raw* | *63107010* | *080300* |
| *Egg, whole* | *31103010* | *040700* |
| *Coffee, espresso* | *92101610* | *090121* |
| *chicken (raw)* | *(SR Legacy) 171057* | *010599* |
| *romaine lettuce, raw* | *72116000* | *070519* |

| | | |
|---|---|---|
| *Tomatoes, raw* | *74101000* | *070200* |
| *vinegar* | *64401000* | |
| *mustard* | *75506010* | *120750* |
| *Bread, whole wheat* | *51300110* | *110100a* |
| *Ground beef, raw* | *21500000* | *020130* |
| *onion* | *75117020* | *071220* |
| *water (tap)* | *94000100* | |
| *tomato sauce* | *74201003* | *070200b* |
| *oregano* | *(SR Legacy) 171328* | |
| *sugar* | *91101000* | *170199* |
| *garlic powder* | *(SR Legacy) 171325* | *070320a* |
| *rosemary* | *(SR Legacy) 171333* | |
| *spaghetti* | *(SR Legacy)168927* | *110100b* |
| *Parmesan cheese (shredded)* | *14108010* | *040620* |
| *broccoli (frozen)* | *72201212* | *070410* |
| *white roll* | *51150000* | *110100a* |
| *pudding mix (instant vanilla)* | *(SR Legacy)168784* | |
| *Popcorn, air-popped* | *54403040* | *1005* |
| *Orange, raw* | *61119010* | *080510* |
| *Egg omelet* | *32130010* | *040700* |
| *Turkey or chicken and pork sausage* | *25221870* | *160242* |
| *Bread, whole wheat, toasted* | *51300120* | *110100a* |
| *Jelly, all flavors* | *91401000* | |

| | | |
|---|---|---|
| apple juice | 64104010 & 92550360 | 200970 |
| Cornmeal (or Polenta) | (Branded) 519405 | 110313 |
| whole kernel corn mixed with vegetables | (SR Legacy) 169218 | |
| green chiles | (Branded) 1182684 | 070960 |
| cheddar cheese (shredded) | 14104100 | 040620 |
| black beans (canned) | 41102080 | 071331 |
| red sweet pepper | 75122200 | 090420 |
| Green beans, raw | 75101800 | 070820 |
| Pretzels, soft, NFS | 54408400 | |
| Oats, raw | 57602100 | 100400 |
| maple syrup | 91300010 | 170220 |
| walnuts, black, dried(chopped) | (SR Legacy) 170186 | 080232 |
| Carrots, raw, salad | 73101110 | 070610 |
| banana pudding | 13241000 | |
| beef round steak | (SR LEGACY) 168712 | 02022 |
| garlic clove | 75111500 | 070320 |
| Lemon juice, 100%, freshly squeezed | 61204010 | 080530 |
| potatoes, boiled | 71102980 | 070190 |
| Butter, tub | 81101010 | 040510 |
| eggs | 31101010 | 040700 |
| baking soda | (SR LEGACY) 175040 | |
| baking powder | (SR LEGACY) 172805 | |
| grapes | 63123000 | 080610 |

| | | |
|---|---|---|
| *eggs fried* | *31105030* | *040700* |
| *celery* | *75109000* | *070940* |
| *fish fillets (atlantic cod)* | *(SR LEGACY) 171955* | |
| *buttermilk* | *11115100* | *040390* |
| *hot sauce* | *75511010* | |
| *onion powder* | *(SR LEGACY)  171327* | |
| *corn flakes (crumbled or regular bread crumbs)* | *57134000* | *110419* |
| *sage (ground)* | *(SR LEGACY) 170935* | |
| *couscous* | *56207160* | *100110/100190* |
| *milk, fat free* | *11113000* | *040110* |
| *baking soda* | *(SR LEGACY) 175040* | |
| *baking powder* | *(SR LEGACY) 172805* | |
| *tofu* | *174291 & (SRLegacy) 172450* | *120100b* |
| *bean sprouts* | *75101000* | *071331* |
| *salsa* | *74402150* | *070200b* |
| *green pepper* | *75122100* | *070960* |
| *apple* | *63101000* | *080810* |
| *yogurt, plain* | *11411400* | *040310* |
| *ranch dressing* | *(SR LEGACY) 173592* | |
| *lentils* | *(SR Legacy) 172420* | *071340* |
| *chili powder* | *(SR Legacy) 171319* | |
| *brown rice* | *56205018* | *100620* |
| *pears (canned)* | *63137110* | *080820* |
| *vanilla yogurt (lowfat)* | *(SR Legacy)  170907* | *040310* |

| | | |
|---|---|---|
| *Nuts, pistachio nuts, raw* | *(SR Legacy) 170184* | *080250* |
| *vanilla extract* | *(SR Legacy) 173471* | *090500* |
| *syrup* | *91301100* | *170199* |
| *pancake syrup* | *91300100* | |
| *pork chop (pan-fried)* | *22101210* | *020319* |
| *baked potato* | *71101000* | *070190* |
| *cabbage (green, shredded)* | *75103000* | *070511* |
| *Milk, low fat (1%)* | *11112210* | *040110* |
| *Cereal, muesli* | *57308190* | *110412* |
| *spaghetti* | *(SR Legacy) 168955* | *110100b* |
| *Egg, whole, fried no added fat* | *31105010* | *040700* |
| *Cheese, Parmesan, dry grated, reduced fat* | *14108015* | *040620* |
| *mushrooms* | *75219011* | |
| *Turkey, NFS* | *24201000* | *160231* |
| *Cheese, Gouda or Edam* | *14105010* | *040610* |
| *Yogurt, low fat milk, plain* | *11411200* | *040310* |
| *Pear, raw* | *63137010* | *080820* |
| *Bread, whole grain white* | *51300050* | *110100a* |
| *Tahini* | *43103300* | *120740* |
| *Chicken breast, baked, broiled, or roasted, skin eaten, from raw* | *24122130* | *010599* |
| *Zwieback toast, rusk* | *51188500* | |
| *Cheese, Feta* | *14104400* | *040610* |

| | | |
|---|---|---|
| *Bagel, thin* | *51180010* | |
| *Tangerine, raw* | *61125010 & (SR Legacy) 169105* | *080520* |
| *Corn, canned, reduced sodium, cooked, no added fat* | *75216310* | *1005* |
| *Mullet, baked or broiled, no added fat* | *26123121* | |
| *Potato, boiled, from fresh, peel eaten, made with oil* | *71103135* | *070190* |
| *Rice, white and wild, cooked, no added fat* | *56205300* | *100630* |
| *Spinach, raw* | *72125100* | *070970* |
| *dill weed, fresh* | *(SR Legacy) 172233* | |
| *Onions, green, raw* | *75117010* | *070310* |
| *Sardines, cooked* | *26139110* | |
| *broccoli* | *72201100* | *070410* |
| *Bread, white* | *51101000* | *110100a* |
| *Beets, raw* | *75102500* | *070690* |
| *Beet greens, raw* | *72101100* | *070690* |
| *Cheese spread, cream cheese, regular* | *14420200* | *040630* |
| *chicken, roasted, breast* | *(SR Legacy) 174608* | *010599* |
| *Broccoli, fresh, cooked, no added fat* | *72201211* | *070410* |
| *almonds* | *42101000* | *080212* |
| *Tortilla, whole wheat* | *52215260* | *110100* |
| *Lettuce, arugula, raw* | *75113080* | *070519* |
| *Olives, black* | *75510020* | *171120* |

| | | |
|---|---|---|
| *Green peas, raw* | *75120000* | *070810* |
| *Vinegar, balsamic* | *(SR Legacy)172241* | |
| *Yogurt, Greek, low fat milk* | *11411410* | *040310* |
| *chickpeas* | *(SR Legacy) 173756* | *071320* |
| *Basil, raw* | *75109400* | |
| *Artichoke, raw* | *75100750* | *070910* |
| *Salmon, baked or broiled, no added fat* | *26137123* | |
| *Squash, zucchini, baby, raw* | *(SR Legacy) 168565* | *070990_b* |
| *almond milk* | *11350020* | |
| *oat flakes* | *57602500* | *110412* |
| *frozen berries* | *63219610* | *081120* |
| *flax seeds* | *43104000* | |
| *rice* | *56205210* | *100630* |
| *Beans, from dried, NS as to type, no added fat* | *41101020* | *071339* |
| *vegetable broth* | *75657000* | |
| *nutritional yeast* | *75236000* | |
| *soy* | *41420300* | *120100* |
| *potato* | *71508001* | *070190* |
| *pink lentils* | *(SR LEGACY) 174284* | *071340* |
| *tomato puree* | *(SR Legacy)170460* | *070200d* |
| *allspice seeds (ground)* | *(SR LEGACY) 171315* | *070960* |
| *bay leaf* | *(SR LEGACY) 170917* | |
| *star anise spike (ground)* | *(SR LEGACY) 171316* | *090910* |

| | | |
|---|---|---|
| *red beans* | *(SR Legacy) 173744* | *071332* |
| *breadcrumbs* | *(Branded) 388506* | *110100a* |
| *coriander fresh* | *(SR Legacy)170922* | *090920* |
| *cumin (ground)* | *(SR Legacy)170923* | |
| *cinnamon (ground)* | *(SR Legacy)171320* | *090620* |
| *cauliflower* | *75214011* | *070410* |
| *barley, pearled, raw* | *(SR Legacy) 170284* | *110421* |
| *Blackeyed peas* | *41301010* | *17133_b* |
| *capers* | *(SR Legacy) 172238* | |
| *Eggplant, raw* | *75111200* | *070930* |
| *vegan cheese* | *(Branded) 1176161* | *120100b* |
| *vegan mayo* | *83108000* | *120100a* |
| *walnuts* | *42116000* | *080232* |
| *hazelnuts* | *42107000* | *080222* |
| *giant beans* | *(SR LEGACY) 175202* | *070820* |
| *cloves (ground)* | *(SR LEGACY) 171321* | *090700* |
| *corn wafers* | *54339000* | *1005* |
| *Pesto sauce* | *81302070* | |
| *saffron stems* | *(SR Legacy) 170934* | |
| *ginger* | *(SR Legacy) 170926* | *091010* |
| *nutmeg (grated)* | *(SR Legacy) 171326* | *0908* |
| *flour, whole-wheat* | *(SR Legacy) 168944* | *110100* |
| *leek, raw* | *75112500* | |
| *spearmint, dry* | *172239* | |
| *split peas* | *41303000* | *071339* |

| | | |
|---|---|---|
| *greens* | *72122100* | |
| *Pasta, whole grain* | *56132990* | *110100b* |
| *parsley, fresh, chopped* | *(SR Legacy) 170416* | |
| *Lettuce, raw* | *75113000* | *070519* |
| *Cilantro, raw* | *75109550* | |
| *Parsley, raw* | *75119000* | |

*Note: Some food items not included in WF databased were found in other sources or omitted*