Review / Derleme

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Sustainable Dietary Patterns and Alternative Food Sources*

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Abstract: Sustainable nutrition ensures optimal dietary intake by evaluating the life cycle of foods and their environmental impacts, aiming to meet current needs without jeopardizing the ability of future generations to do the same. It is characterized by low greenhouse gas emissions, minimal water footprint, efficient energy and land use, and reduced food waste. Sustainable dietary models, which have become increasingly important in the face of rising food demand and climate change challenges, include the Mediterranean Diet, Nordic Diet, DASH (Dietary Approaches to Stop Hypertension) Diet, Double Pyramid Model, Flexitarian Diet, EAT-Lancet Commission Reference Diet, and Vegetarian and Vegan diets. Alternative protein sources such as algae, insects, and cultured meat are also significant. Algae offer sustainability through ocean use but have unclear metabolic impacts. Insects are efficient and environmentally friendly but require safety assessments. Cultured meat promises environmental benefits but faces cost and acceptance hurdles. Promoting sustainable eating habits requires a collective effort and is a shared responsibility towards our planet and ourselves.

Keywords: Sustainability, Sustainable Diets, Alternative Protein Source, Innovative Food Applications.

JEL Classification: M31, E21, D11

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Sürdürülebilir Beslenme Modelleri ve Alternatif Gıda Kaynakları

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Öz: Sürdürülebilir beslenme, gıdaların yaşam döngüsünü ve çevresel etkilerini değerlendirerek, mevcut ihtiyaçları karşılarken gelecek nesilleri tehlikeye atmadan optimal diyet alımını garanti eder. Düşük sera gazı emisyonları, minimum su ayak izi, verimli enerji ve arazi kullanımı ve azaltılmış gıda israfı ile karakterize edilir. Artan gıda talebi ve iklim değişikliği zorluklarıyla birlikte giderek daha önemli hale gelen sürdürülebilir diyet modelleri arasında Akdeniz Diyeti, İskandinav Diyeti, DASH Diyeti (Hipertansiyonu Durdurmak İçin Diyet Yaklaşımları), Çift Piramit Modeli, Esnek Vejetaryen Diyeti, EAT-Lancet Komisyonu Referans Diyeti ve Vejetaryen ve Vegan diyetleri bulunur. Algler, böcekler ve kültürlenmiş et gibi alternatif protein kaynakları da önemlidir. Algler, okyanus kullanımından dolayı sürdürülebilirlik sunar, ancak metabolik etkileri belirsizdir. Böcekler, verimli ve çevre dostudur, ancak güvenlik değerlendirmeleri gerektirir. Kültürlenmiş et, çevresel faydalar vaat eder, ancak maliyet ve kabul edilebilirlik engelleriyle karşı karşıyadır. Sürdürülebilir beslenme alışkanlıklarını teşvik etmek kolektif bir çaba gerektirir ve gezegenimize ve kendimize karşı ortak bir sorumluluktur.

Anahtar Kelimeler: Sürdürülebilirlik, Sürdürülebilir Diyetler, Alternatif Protein Kaynağı, Yenilikçi Gıda Uygulamaları.

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GENİŞLETİLMİŞ ÖZ

Araştırma Problemi

Bu derlemenin amacı, çeşitli diyet modellerini ve alternatif gıda kaynaklarını sürdürülebilirlik perspektifinden değerlendirerek sürdürülebilir bir beslenme sistemine olan potansiyel katkılarına odaklanmaktır.

Araştırma Soruları

Sürdürülebilirlik perspektifinden bakıldığında çeşitli diyet modelleri ve alternatif gıda kaynakları sürdürülebilir bir beslenme sistemine nasıl katkıda bulunur?

Literatür Taraması

Sürdürülebilir beslenme kavramı, günümüzün en kritik meselelerinden biridir. Çevresel etkileri azaltarak hem insan sağlığını korumayı hem de doğal kaynakların tükenmesini önlemeyi hedefler. Küresel ölçekte giderek daha fazla önem kazanan bu kavram, gıdaların yaşam döngüsünü ve çevresel etkilerini değerlendirerek, mevcut ihtiyaçları karşılarken, gelecek nesillerin de aynı şekilde beslenme imkanına sahip olmasını garanti altına almayı amaçlar. Bu yaklaşım, yalnızca günümüzdeki sorunları çözmekle kalmaz, aynı zamanda uzun vadeli sürdürülebilirlik ve refahı da hedefler. Sürdürülebilir beslenme, düşük sera gazı emisyonları, minimum su ayak izi, enerji ve arazi kullanımında verimlilik ve gıda israfının azaltılması gibi temel özelliklerle karakterize edilir. Bu özellikler, yalnızca çevresel sürdürülebilirliği artırmakla kalmaz, aynı zamanda insan sağlığı üzerinde de olumlu etkiler yaratır. Sürdürülebilir beslenmenin temel stratejileri, gıda üretiminin çevresel ayak izini en aza indirmek, bitki bazlı diyetleri teşvik etmek ve gıda israfını azaltmak etrafında şekillenir. Bu stratejiler, kaynakların daha verimli kullanılmasını sağlarken, aynı zamanda toplumların beslenme alışkanlıklarını da daha sağlıklı ve çevre dostu hale getirir. Artan dünya nüfusu ve bu nüfusun artan gıda talebi, sürdürülebilir diyet modellerinin önemini her geçen gün daha da artırmaktadır. İklim değişikliği gibi küresel zorluklarla birlikte ele alındığında, bu modellerin benimsenmesi kaçınılmaz hale gelmiştir. Genellikle bitki bazlı ve mevsimsel tüketime dayalı olan bu diyet modelleri, aynı zamanda kültürel olarak da kabul edilebilir olmalıdır. Farklı kültürlerde başarıyla uygulanmış örnekler arasında Akdeniz Diyeti, İskandinav Diyeti, DASH Diyeti, Çift Piramit Modeli, Esnek Diyet, EAT-Lancet Komisyonu Referans Diyeti gibi modeller ile Vejetaryen ve Vegan diyetleri yer alır. Bu modeller, çevresel etkileri azaltırken, beslenme alışkanlıklarını da sağlıklı bir şekilde dönüştürme potansiyeline sahiptir. Alternatif protein kaynakları da sürdürülebilir beslenme için önemli bir bileşen olarak ortaya çıkmaktadır. Yosun, böcek ve kültürlü et gibi bu alternatifler, geleneksel hayvansal protein kaynaklarına kıyasla daha düşük çevresel etkilere sahiptir. Yosunlar okyanus kullanımı yoluyla sürdürülebilirlik sunarken, metabolik etkileri henüz tam olarak anlaşılmamıştır. Böcekler ise verimli ve çevre dostu bir protein kaynağı olmasına rağmen, gıda güvenliği açısından kapsamlı değerlendirmeler gerektirmektedir. Kültürlenmiş et ise, potansiyel çevresel faydalar sunmasına rağmen, maliyet ve tüketici kabulü gibi önemli zorluklarla karşı karşıyadır. Sürdürülebilir beslenme alışkanlıklarının yaygınlaştırılması, sadece bireysel çabalarla değil, toplumsal düzeyde kolektif bir çaba gerektirir. Bu, hem gezegenimize hem de kendimize karşı ortak bir sorumluluğumuzdur. Sürdürülebilir bir gelecek inşa etmek için, hem mevcut gıda sistemlerini dönüştürmemiz hem de yeni, daha sürdürülebilir beslenme modellerini benimsememiz gerekmektedir.

Sonuç

The Sürdürülebilir beslenme hem bireysel sağlığı koruyan hem de çevresel sürdürülebilirliği destekleyen bir yaklaşımdır. Artan gıda talebi ve iklim değişikliği ile birlikte, bitki bazlı diyetler ve çevresel etkisi düşük alternatif protein kaynakları, sürdürülebilir beslenmenin kritik unsurları haline gelmiştir. Akdeniz Diyeti, İskandinav Diyeti ve EAT-Lancet Komisyonu Referans Diyeti gibi modeller, sürdürülebilir beslenme için örnek teşkil eder. Ayrıca, algler, böcekler ve yapay et gibi alternatif gıda kaynakları, çevresel baskıyı azaltmada önemli bir rol oynayabilir. Bu diyetlerin ve gıda kaynaklarının yaygınlaştırılması, gelecek nesillerin sağlığını ve doğal kaynaklarını korumak için elzemdir. Bu hedefe ulaşmak için bireylerden hükümetlere kadar geniş bir katılım ve iş birliği gereklidir.

INTRODUCTION

The increasing global population, climate change, loss of biodiversity, and the limited availability of energy and water resources pose significant threats to future generations (Tompa et al., 2020). Pollution of resources, inefficiency, greenhouse gas emissions, increased water consumption, land use expansion, global warming, and hunger are just a few examples of these pressing issues (Foley, 2011). To address these issues, efforts to study and implement the concept of sustainability have been initiated since the 1970s (Olgun et al., 2022). One of the ways to mitigate these threats is by regulating individuals' food choices. These regulations have led to the emergence of the concept of "sustainable diets" in recent years (Ünal-Özen, 2019). The term "sustainable diets" was introduced by Gussow and Clancy in 1986 to describe recommendations for healthy food choices that align with the limits of future natural resources (Gussow and Clancy, 1986). The use of natural resources at all stages of the farm-to-table process has elevated the importance of sustainability in nutrition (Willett et al., 2019).

Sustainability is defined as the efficient use of resources while considering the needs of the present world and future generations (Galanakis, 2019). The environmental impact of increasingly prominent food production is determined by calculating the carbon footprint of resources used throughout the entire process. The carbon footprint is the total amount of greenhouse gases expressed in kilograms per product emitted during its production, use, and final disposal (Clune et al., 2017). Sustainable nutrition is generally defined as the ability to meet today's needs without compromising the ability of future generations to meet their nutritional requirements, ensuring the continuity of a system over the long term (United Nations, 2016). According to the definition provided by the Food and Agriculture Organization (FAO), sustainable nutrition is the nutrition that is harmonious with ecosystems and biological diversity, accessible, culturally acceptable, economically fair to all individuals, nutritionally adequate, reliable, and healthy (Spiker et al., 2020; FAO, 2019). Key considerations for sustainable nutrition include addressing increasing environmental pollution and declining resources. Therefore, it is necessary to prefer alternative sources and dietary patterns that have positive effects on both the environment and individuals, as opposed to food sources that have negative impacts on the environment (Can et al., 2021).

Sustainable nutrition encourages minimizing the environmental impact of food choices related to production, reducing food waste and losses, consuming locally and seasonally appropriate foods, and promoting the consumption of plant-based foods instead of animal-based and high-fat foods (Demir and Akay, 2020; Yolcuoğlu and Kızıltan, 2021). While the concept of sustainable nutrition is not new, its goal is to ensure optimal growth and development for all individuals, support the physical, mental, and social well-being of future generations, prevent malnutrition, and preserve environmental health (FAO, 2012; Johnston et al., 2014). Sustainable food systems encompass three primary goals: economic, social, and environmental, all of which are aligned with the objectives mentioned earlier (FAO, 2010). Firstly, sustainable food systems should provide better alternatives in terms of economic goals. As an example of these alternatives, in developed countries, the affordability of animal-based foods stands out, especially compared to plant-based foods. The increased consumption of economically accessible products can create a chain that leads to environmental harm (Broekema et al., 2020). From a social perspective, it is crucial that everyone has access to foods that align with traditional dietary habits, and that the content of the food system is in harmony with socio-cultural variables such as health and working conditions (The Lancet Commission Report, 2019).

Another goal, the environmental goal, aims to consider the ecological impacts of sustainable food systems at all stages from production to consumption. The process starting from food production should continue to consider biodiversity, water and carbon footprint, as well as environmental and human health, through processing, transportation, and up to consumption. When considering nutrition models from all these perspectives, the environmental impact of animal-based foods, which tends to be higher than plant-based foods (Koyuncu and Akgün, 2017), highlights the prominence of plant-based dietary models. It has been concluded that the concept of sustainable nutrition actually encompasses comprehensive control over the entire food system, being broad and multidisciplinary in nature (Broekema et al., 2020). It is anticipated that proper guidance and steps taken in the food system will address climate change, diet-related diseases, and food insecurity (The Lancet Commission Report, 2019). In addition, not every dietary model deemed healthy is sustainable, and not every dietary model deemed sustainable is necessarily healthy (Béné et al., 2019). To achieve alignment between sustainable nutrition models and health, it is necessary to develop specific recommendations that each individual can accept and adopt (Gülsöz, 2017).

In this review, various diets practiced by different societies are evaluated as sustainable nutrition models. These include the Mediterranean Diet, Nordic Diet, Vegetarian and Vegan Diets, Flexitarian Diet, DASH Diet, EAT-Lancet Commission Reference Diet (Planetary Health Diet), and Double Pyramid Model, assessed from a sustainability perspective. Additionally, alternative food sources that could contribute to ensuring a sustainable nutrition system (such as edible insects, artificial meat, and edible seaweeds) have been considered.

2. SUSTAINABLE DIETARY MODELS

2.1. Mediterranean Diet

The Mediterranean Diet is a multifaceted dietary pattern that emerged with the beginning of life in Mesopotamia. It is a blend of various culinary traditions from countries in the Mediterranean region, including Albania, Algeria, Greece, Egypt, Turkey, France, Italy, Lebanon, Malta, Morocco, Portugal, Spain, and Tunisia. It should be noted that, in addition to being a diet where the cultures of various countries converge on a common theme, it is not a dietary pattern with a single type or strict rules. The Mediterranean Diet is characterized by a rich diversity of foods. It includes high levels of olive oil, vegetables, fruits, whole grains, legumes, and nuts; moderate amounts of low-fat dairy products, wine, eggs, poultry, fish, and seafood; and low amounts of red meat, saturated fats, and sugary foods (Gümüş, 2020). In regions where it aligns with social norms and religious beliefs, wine consumption is quite prevalent (Bach-Faig et al., 2011). It is a dietary model that emphasizes olive oil and olives, which are low in trans fats and rich in monounsaturated fatty acids, vitamins, minerals, and phytochemicals (Vitiello et al., 2016). The diet emphasizes the consumption of fresh, seasonal, minimally processed, and, if possible, local foods. Regular moderate physical activity, adequate rest, spending time in the kitchen, and engaging in enjoyable activities are important aspects of this dietary model (Bach-Faig et al., 2011). The Mediterranean Diet is a model where nutrition, biodiversity, local food production, culture, and sustainability are strongly interconnected (Burlingame and Dernini, 2011). The Mediterranean Diet is distinguished from other dietary models by its foundation in low environmental impact food groups such as vegetables, fruits, and grains, and its recommendation of red meat consumption in minimal amounts, which reduces environmental burden (Dernini et al., 2017). Although the Mediterranean Diet has been studied since the 1960s for its ability to reduce morbidity and mortality as a healthy eating program, it was Joan Dye Gussow in the 1990s who recognized its plant-centered nature, which requires fewer energy resources, water, and land, and has a lower impact on the ecosystem. This led to its investigation as a sustainable dietary program (De Lorgeril, 1995). In recent years, the Mediterranean Diet has been the subject of numerous studies under sustainable diets due to its plant-based nature, which results in lower greenhouse gas emissions and a reduced water footprint compared to Western diets.

In 2010, a scientific symposium organized by the FAO defined sustainable nutrition, and the Mediterranean Diet was shown to align with this definition (Dernini and Berry, 2015). In Spanish society, increasing adherence to the Mediterranean Diet has been associated with reductions in greenhouse gas emissions (72%), land use (58%), energy consumption (52%), and water use (33%). Conversely, increased adherence to a Western dietary pattern has been linked to a 12-72% increase in these environmental impacts (Sáez-Almendros et al., 2013). From a health perspective, adherence to the Mediterranean Diet has demonstrated beneficial effects on cardiovascular diseases (Estruch et al., 2018; Rosato et al., 2019), obesity, diabetes, and metabolic syndrome. It also shows therapeutic benefits in the management of cancer and neurodegenerative diseases, contributing to overall health improvement (Kastorini et al., 2011; Barbaros and Kabaran 2014; Huo et al., 2015; Gotsis et al., 2015; Obeid et al., 2022). Higher adherence scores to the Mediterranean Diet have been observed to be associated with lower plasma lipids, glycated hemoglobin, blood pressure, and body mass index (BMI) (Vitale et al., 2018). Another study identified a linear trend between adherence to the Mediterranean Diet and quality of life, suggesting that greater adherence to a healthy eating pattern is associated with better quality of life measurements (Godos et al., 2018). In 2010, the Mediterranean Diet was added to UNESCO (United Nations Educational, Scientific, and Cultural Organization)'s Intangible Cultural Heritage of Humanity list. The significance of the Mediterranean Diet extends beyond specific foods and nutrients to include the production, preparation, and consumption methods of its characteristic foods (Dernini and Berry, 2015).

Today, the main concern for the Mediterranean food and agriculture sector is the inability to preserve natural resources for future generations while also providing sufficient quantities and quality of food to meet the needs of a growing population. Therefore, sustainable nutrition is considered crucial as it is anticipated to benefit both food consumption and food production, thus contributing to greater food and nutrition security (CIHEAM/FAO, 2015). It is well-known that meat production in the food sector ranks high in terms of greenhouse gas emissions, water consumption, and soil degradation. Numerous studies have also demonstrated that diets with high consumption of animal-based foods threaten the sustainable use of natural resources (Belahsen, 2014). Considering that excessive red meat consumption is linked to diseases such as cardiovascular conditions, cancer, and diabetes (Larsson et al., 2011; Micha et al., 2010; Pan et al., 2011), the lower red meat consumption in the Mediterranean Diet makes it more preferable compared to other diets from both health and sustainability perspectives. A study conducted in the U.S. (United States) demonstrated that, similar to the Mediterranean Diet, replacing red meat with fish, eggs, and legumes results in a noticeable reduction in CO_2 (carbon dioxide) emissions (Weber and Matthews, 2008). Another study conducted in the UK (United Kingdom) found that reducing red meat consumption and increasing the intake of vegetables, fruits, and grains could lead to a 19% reduction in greenhouse gas emissions (Scarborough et al., 2012). In the Mediterranean Diet, legumes, which are an important source of protein, have a much lower carbon footprint compared to beef, the most common protein source in Western diets. These features contribute to lower greenhouse gas emissions, reduced water footprint, and improved use of arable land. Although vegan diets are generally among the most environmentally sustainable, the Mediterranean Diet can lead to better overall environmental outcomes compared to high-fat vegan diets, which contains more fats, nuts, and have a higher water footprint (Coats et al., 2020; Echeverría et al., 2020; Chai et al., 2019). Additionally, the Mediterranean Diet helps reduce transportation-related carbon footprints by incorporating locally produced foods (Serra-Majem and Ortiz-Andrellucchi, 2018). According to these studies, it can be said that the foods in the Mediterranean Diet have a lower overall impact on the ecosystem.

2.2. Nordic Diet

Since 1980, Scandinavian countries have developed the Nordic Diet (ND), which takes a holistic approach by evaluating all components of the diet to meet the energy, macro, and micronutrient needs of their populations, focusing on nutritional reference values for different age groups (Yüksel and Özkul, 2021). It is a prototype regional diet that considers health, food culture, taste, and the environment. It has been successfully tested in some regions of Northern Europe and was initially implemented in a region of the Netherlands (Bügel et al., 2016). This diet is characterized by high amounts of local fruits and vegetables, fresh herbs, potatoes, plants and mushrooms, whole grains, nuts, fish and shellfish, seaweed, free-range farm animals (including pigs and poultry), and game animals (Mithril et al., 2013).

In a comprehensive study conducted by the University of Eastern Finland, the Finnish Heart Association, and the Finnish Diabetes Association, the Baltic Sea Diet Pyramid was developed (Adamsson et al., 2012). Foods that are most important for health and should be consumed the most are located at the bottom of the pyramid. Scandinavian vegetables, cabbage, peas, fruits, grains (such as whole rye, oats, barley), fiber-rich foods, fish, low-fat or fat-free dairy products, and canola oil are located in the center of the pyramid. Processed meats, butter, sweets, chocolate, and sweet baked goods, which should be consumed in smaller quantities, are positioned at the top of the pyramid. Due to its important role as a source of calcium and protein in the diet, milk is the only beverage shown in the pyramid. Water is generally recommended to meet hydration needs, while moderate consumption or restriction of alcoholic beverages is advised (Kanerva et al., 2014). The vision of Scandinavian cooperation for 2030 is to make the Scandinavian region the most sustainable and integrated area in the World (Nordic Co-operation, 2021). In addition to emphasizing sustainability, this dietary approach has established three key consumption goals for improving health and preserving cultural heritage: reducing red meat consumption in favor of obtaining more calories from plant-based foods, increasing the intake of food sources from the sea and lakes, and sourcing more food from wild rural areas (Mithril et al., 2012). The recommendations include increasing the consumption of whole grains, plant-based oils instead of solid fats, low-fat dairy products, fruits, vegetables, and seafood, while reducing red and processed meats, sugary beverages, salt, and alcohol (Nordic Council of Ministers, 2014).

The fact that Nordic countries are surrounded by seas has significantly contributed to the emergence of this dietary pattern, which has encouraged the consumption of high-quality fish, seaweed, and shellfish. Nevertheless, the consumption of farmed fish instead of wild-caught fish leads to a reduction in the intake of healthy fish oils, as farmed fish are fed with plant-based oils due to the insufficient availability of waste fish as feed (Fernandez-Jover et al., 2007). Therefore, the Nordic Diet focuses on wild species and promotes their sustainable fishing practices. In the Nordic countries, the consumption of various wild-harvested mushrooms, plants, and fruits has been encouraged in the Nordic Diet due to their minimal environmental impact (Mithril et al., 2012). Since wild plants and mushrooms grow without the need for fertilizers, pesticides, or external energy costs, they have a significantly lower negative environmental impact compared to conventional food production. However, there are limitations on the amount of food that can be foraged from wild areas before causing a negative impact on the environment. Nevertheless, it is estimated that only 2–4% of wild fruits in the Nordic region are foraged and consumed by humans, while the remaining 96–98% are consumed solely by birds and wildlife. The same situation applies to many other plants and foods; therefore, they should be utilized to a greater extent (and as needed) (Battino et al., 2009; Bere, 2007).

In the Nordic countries, greenhouse-grown foods hold great potential in terms of product diversity. However, new facilities increasingly rely on renewable energy sources such as geothermal heat, heat pumps powered by 'green' electricity, or heat supplied by biogas. The use of green energy in greenhouse production ensures the availability of fresh fruits and vegetables in the Scandinavian climate throughout all seasons, while also reducing energy costs, making these products more affordably accessible. Thus, it is anticipated that the consumption of frozen foods will be reduced, minimizing environmental harm to the lowest possible level (Halloran et al., 2018). Regionally produced foods are environmentally sustainable, so by increasing the consumption of local products, food transportation from production to consumption is minimized, thereby reducing some negative environmental impacts. Increasing regional consumption and utilizing seasonal products and foods from rural areas also benefit the environment. From an environmental impact perspective, incorporating organic products into the Nordic Diet is more advantageous compared to the Danish diet. In some cases, organic products have a lower environmental impact compared to conventional products, and this is considered an advantage (Ceyhun-Sezgin et al., 2023). Additionally, adopting organic production principles primarily preserves nature and biodiversity, highlighting the well-being of soil, water, plants, animals, and humans. In developing countries, organic farming practices can not only increase current yields but also be the only alternative for a more sustainable approach in the long term (Saxe, 2014). Among the similarities between the Mediterranean Diet and the Nordic Diet are the inclusion of large amounts of vegetables, fruits, whole grains, fish, and low-fat dairy products, along with plant-based proteins, and the inclusion of smaller amounts of meat products, sugary, and processed foods. Additionally, this dietary model focuses on minimizing waste and using every part of the purchased food. It aims to encourage biodiversity by incorporating foods obtained from wild rural areas into the diet and minimizing the use of fertilizers and pesticides (Mithril et al., 2012).

The health effects of this dietary model are being investigated through extensive, multi-center studies (Ramezani-Jolfaie et al., 2019). Intervention studies using biomarkers such as blood lipid profiles, insulin sensitivity, blood pressure, and low-grade inflammation-factors associated with cardiovascular risk-have found that the Nordic Diet has positive effects (Kanerva et al., 2012; Lankinen et al., 2019). Additionally, the Nordic Diet has been compared with other diets, such as the DASH diet, concerning blood pressure, an important indicator of cardiovascular health. Due to the Nordic Diet's structure, which emphasizes high consumption of fresh vegetables and fruits, it has been reported that the increased intake of flavonoids contributes to a reduction in blood pressure (Ndanuko et al., 2016). A study investigated the effects of the Nordic Diet and the Danish Diet on the health of 147 individuals with metabolic syndrome (average age: 42; BMI: 32; 70% female). The study found a reduction in blood pressure and body weight loss among those following the Nordic Diet. In conclusion, it has been emphasized that the Nordic Diet, like the Mediterranean Diet and the DASH diet, has positive effects on health (Poulsen et al., 2014). Regarding its health effects, the Nordic Diet has been shown to positively impact blood lipids compared to a normal eating pattern, reduce LDL cholesterol levels, and regulate inflammatory markers (Uusitupa et al., 2013).

Observational cohort studies have shown that high adherence to the Scandinavian diet is associated with lower mortality, reduced inflammation markers, a decreased risk of colorectal cancer, less body fat and consequently lower obesity rates, and healthier weight gain in children (Lankinen et al., 2019). The World Health Organization (WHO) has regarded the Nordic Diet as similar to the Mediterranean Diet in terms of its health-promoting and supportive features (Ndanuko et al., 2016). Among sustainable dietary models, the Nordic Diet has significant potential for being adapted to any region of the world by applying the principles and fundamentals of local and traditional diets (Bügel et al., 2016).

2.3. Vegetarian and Vegan Diets

Vegetarian nutrition and its various models are currently adopted by consumers due to factors such as health concerns, rapid transformations in the food system, lifestyle changes, and individual preferences (Kahleova et al., 2022). Vegan and vegetarian diets generally include high amounts of fruits, vegetables, whole grains, legumes, nuts, and soy products, and involve low intake of saturated fats (Melina et al., 2016). Vegetarian diets are defined by the partial exclusion of animal-derived sources and are heterogeneous in terms of nutritional practices (Allès et al., 2017; McEvoy et al., 2012). Vegetarian nutrition diets include various types such as vegan, lacto-vegetarian, lacto-ovo-vegetarian, semi-vegetarian, and partial vegetarian. The lacto-ovo-vegetarian diet includes grains, vegetables, fruits, legumes, oily seeds, dairy products, and eggs. The lacto-vegetarian diet excludes eggs, fish, meat, and poultry (Ceyhun-Sezgin and Ayyıldız 2017; Şanlıer and Ertaş 2018). Vegan nutrition is a dietary approach that eliminates all primary and secondary animal-derived products, including those made from these products (such as leather, wool, and silk). It is also a strict lifestyle (Vanacore et al., 2018). However, there are also types such as pescatarians, who consume only fish, and flexitarians, who may occasionally include small amounts of meat (Paslakis et al., 2020). The vegan diet prohibits (a) animal products (meat, poultry, fish, eggs, dairy products, beeswax, honey, leather products); (b) garlic, onions, scallions, green onions, and leeks; (c) products that use animal-derived ingredients in their production, such as rennet obtained from the inner lining of animal stomachs and gelatin derived from animal skins, bones, and connective tissues; and (d) certain sugars that are whitened with bone char (Petti et al., 2017). Due to extensive restrictions in the main food categories, emphasis is placed on the consumption of fruits, vegetables, grains, legumes, nuts, and seeds. Therefore, veganism is typically low in fat and protein but high in carbohydrates (Dixon et al., 2023).

In Western societies, health, environmental impact, and animal rights constitute the primary reasons for individuals choosing a plant-based diet (Hopwood et al., 2020). From a health perspective, vegan and vegetarian diets have been shown to have beneficial effects on various diseases (Appleby et al., 2016; McEvoy et al., 2012). Additionally, these diets have demonstrated positive effects on individuals' body weight, body fat percentage, lean muscle mass, and bone mineral density (Oussalah et al., 2020; Bakaloudi et al., 2021). Studies indicate that these individuals can generally meet nutritional recommendations but may experience deficiencies, particularly in vitamin B12 (Allès et al., 2017). It is emphasized that supplementation is necessary in vegetarian diets due to potential deficiencies in vitamins and minerals such as B12, iron, vitamin D, and calcium. It is believed that the addition of foods such as meat and soy milk to vegetarian diets can make the diet healthier. It has been reported that vegan individuals tend to gravitate towards packaged, high-calorie foods (Brytek-Matera, 2020). It has been found that the consumption of sugary beverages is higher among vegetarians, pesco-vegetarians consume less fish compared to those who eat meat, and lacto-ovo vegetarians consume dairy products at levels almost comparable to those of meat-eaters. Discussions about the effects of different vegetarian models on nutrition and health generally depend on the quantity of plant-based foods in the diet (Vergeer et al., 2020). Therefore, by developing lacto-ovo-vegetarian and vegan models, efforts are made to enhance the sustainability level of these diets (Van Dooren et al., 2014). Vegetarian diets generally protect against chronic diseases by preventing inflammation caused by animal products through the high antioxidant content of plant-based foods. Moreover, by consuming fewer calories, vegetarian individuals are protected against obesity and experience a lower incidence of associated chronic diseases (Magkos et al., 2020).

Agriculture alone is responsible for approximately 10-12% of global greenhouse gas emissions. It is projected that greenhouse gas emissions could increase to 150% of current levels by 2030. Therefore, as finding ways to mitigate the negative impacts of climate change and the environmental effects of current food systems becomes increasingly urgent, vegetarian diets are also gaining attention for their sustainability aspects (Weber and Matthews 2008; Friel et al., 2009). It is known that livestock production accounts for 23% of agricultural greenhouse gas emissions, including those considered harmful to the environment such as nitrogen oxides (NO_2), methane (CH_4), and CO_2. On average, 43 kg of greenhouse gas emissions are released for every kilogram of beef produced. Approximately 22 kg of this 43 kg of greenhouse gas emissions consists of methane emissions (Esteve-Llorens et al., 2019; Cleveland and Gee 2017). Overall, excluding animal products, particularly meat and meat products, from the diet has been found to reduce greenhouse gas emissions by 64-80% (Forber et al., 2020). A study found that a 25% reduction in meat consumption and a shift towards vegetarian diets led to an expansion of agricultural land, increased biodiversity, and reduced carbon dioxide emissions (Lynch et al., 2018). Another study shows that for every gram of beef protein consumed in the human diet, beef production requires 42 times more land, 2 times more water, and 4 times more nitrogen compared to staple plant foods, and also produces 3 times more greenhouse gas emissions (Cleveland and Gee 2017). A study on water consumption found that the difference in water use between animal and plant proteins is 26 times greater, with animal protein production requiring 4.4 times more water compared to plant-based protein, even though plant-based proteins also require significant irrigation. Accordingly, a diet with lower animal product content has been shown to reduce global water consumption (Reynolds et al., 2014). However, another study suggests that while vegetarian diet consumers are likely to produce fewer greenhouse gas emissions, this outcome is not guaranteed. For example, substituting cheese for chicken in a diet could lead to increased total greenhouse gas emissions if the energy and nutritional content are not considered and if the production of the vegetarian alternative results in higher emissions (Hyland et al., 2017). Another study evaluated six different diets (average Dutch diet, recommended Dutch diet, vegan, semi-vegetarian, traditional vegetarian, Mediterranean diet) by calculating health scores, sustainability scores, greenhouse gas emissions indices, and land use indices. The vegan diet had the highest health score and was ranked second in sustainability score. The vegetarian diet ranked second in sustainability score and third in health score (Van Dooren et al., 2014). In a prospective cohort study conducted in the Netherlands with 2,834 pregnant women, it was reported that vegetarian pregnant women who chose organic foods and accounted for their intake of macro and micronutrients experienced a healthy process for both mother and baby (Simões-Wüst et al., 2017). Another study found that well-planned vegetarian diets, tailored to the needs of special groups such as endurance athletes, not only enhance performance but also have positive effects on cardiovascular health (Barnard et al., 2019). A comprehensive cohort study has demonstrated positive outcomes of vegetarian diets in terms of both health and environmental impacts (Smetana et al., 2019; Guillaumie et al., 2019).

A widely accepted view today is that plant-based diets, such as vegetarianism, have positive effects on both the environment and health, including aspects like safety, waste management, storage options, and lower greenhouse gas emissions compared to animal-based diets. Although plant-based proteins are often considered to be of lower quality compared to animal-based proteins, a well-planned plant-based diet can be both nutritionally adequate and environmentally sustainable (González-García et al., 2018; Tyszler et al., 2016).

2.4. Flexitarian Nutrition

Flexitarianism is a relatively new term that has emerged in recent times in scientific and public sectors. The term "flexitarian" is a combination of the words "flexible" and "vegetarian" (Derbyshire et al., 2017). It typically refers to an individual who primarily follows a vegetarian diet but occasionally eats meat or fish. Despite global demand for meat, there is an increasing number of flexitarian consumers who regularly avoid eating meat (Dagevos, 2014). Flexitarian diets reflect consumers who eat meat on certain days of the week. The main difference between flexitarian diets and vegetarian or vegan diets is their flexibility. Flexitarian diets provide a means for individuals to obtain forms of protein, lipids, and micronutrients that may be deficient in vegetarian and vegan diets (Braakhuis et al., 2021). This is most compatible with semi-vegetarianism (Derbyshire et al., 2017).

The flexitarian diet, which lacks strict rules and prohibitions, typically recommends the consumption of fruits, vegetables, legumes, and whole grains, obtaining protein from plant sources, minimizing processed meat intake, occasionally adding animal products to the diet, and limiting sugary foods (Streit, 2022). Although it is not always explicitly named, flexitarianism is the default lifestyle for many people around the world. Here, plant-based meals fulfill a significant portion of people's caloric needs. By including essential proteins, lipids, and micronutrients from meat and animal products, a diet can be obtained that ensures these nutrients are not lacking (Hicks et al., 2018).

Research has shown that individuals following a flexitarian diet experience reduced risk of BMI issues, total cholesterol, LDL cholesterol, hypertension, diabetes, and cardiovascular diseases. Additionally, the diet's composition of high-fiber plant-based foods is effective in preventing inflammatory bowel diseases, such as Crohn's disease, and bowel inflammation (Derbyshire et al., 2017). It is presented as a diet model that, in addition to health benefits, prioritizes planetary and animal welfare and is sensitive to environmental issues (Forestell, 2018). The indirect effects of excessive meat production and consumption include issues such as reduced water availability, loss of ecosystems, deforestation, land degradation, and increased water and air pollution. The livestock sector is the largest anthropogenic user of terrestrial surfaces. Livestock production uses 70% of all agricultural land and accounts for 30% of the planet's surface (Steinfeld et al., 2006; Pachauri, 2008). Clearing and managing land for grazing, feed crops, or agriculture is also a significant concern (Henning, 2011). These processes lead to desertification, loss of vegetation, reduction in available water, decreased agricultural productivity, increased salinity, and heightened soil erosion (Pachauri et al., 2014) additionally, they facilitate the invasion of non-native species. The meat industry is also the largest sectoral source of water pollution (Steinfeld et al., 2006). Animal waste (including antibiotics and hormones), waste from slaughterhouses, fertilizers, and pesticides used for feed crops contribute to eutrophication in aquatic environments and pollute groundwater sources. Such pollution further weakens stressed marine ecosystems, such as coral reefs (Steinfeld et al., 2006; Henning, 2011). The impacts of industrial-scale livestock production on ecosystems and species are equally serious, contributing significantly to global deforestation of grazing lands. This situation contributes to an unprecedented and rapid decline in essential ecological functions, such as oxygen supply, climate regulation, flood prevention, soil erosion defense, water recycling and purification, and habitat provision for flora and fauna. Indirectly, all of these factors contribute to climate change (Raphaely and Marinova 2014). A study on the impact of plant-based diets on sustainability found that transitioning from a classic Western diet to a flexitarian diet, with partial removal of meat, led to a 7% reduction in greenhouse gas emissions (Aleksandrowicz et al., 2016). Reducing meat consumption to a healthier eating habit, such as flexitarianism, provides an immediate, accessible, and effective opportunity to mitigate climate change and reduce its negative impacts (Nordgren, 2012).

2.5. DASH Diet

This dietary model is known as the DASH (Dietary Approaches to Stop Hypertension) diet, which is designed as a nutritional approach to prevent hypertension. The DASH dietary model supports the consumption of vegetables, fruits, whole grains, low-fat dairy products, fish and poultry, legumes, plant oils, and nuts, while also restricting the intake of sugars, sugary foods, sweetened beverages, processed and fatty meats, and saturated fats (Medina-Remón et al., 2018). The DASH diet recommends limiting daily sodium intake to 2300 mg (Filippou et al., 2020). The DASH diet focuses on a plant-based nutrition approach aimed at reducing both systolic and diastolic blood pressure by limiting sodium intake. This approach recommends limiting red meat, saturated fats, and foods and beverages with added sugars (Poyraz and Çiftçi, 2022).

The DASH diet, which is recommended for reducing blood pressure and treating hypertension-a major risk factor for cardiovascular diseases-was developed in response to the increasing prevalence of hypertension in the United States during the 1990s (Rifai and Çiftçi, 2016). In healthy individuals over the age of 40, adherence to the DASH diet has been found to be associated with reductions in body weight, BMI, and fat mass, along with an increase in lean body mass. It has been reported that the DASH diet positively affects inflammation markers by being inversely related to C-reactive protein (CRP) (Ko et al., 2016). Observational studies have noted that adherence to the DASH diet is associated with reduced body weight, lower incidence of stroke, decreased risk of heart failure, and a lower risk of cardiovascular diseases. Adherence to the DASH diet has also been associated with a reduced risk of type 2 diabetes and colorectal cancer (Miller et al., 2013). In a study by Navarro-Prado et al. (2020), adherence to the DASH diet was found to be associated with lower blood pressure, reduced abdominal and visceral fat, smaller waist circumference, and a lower incidence of metabolic syndrome (MetS) (Navarro-Prado et al., 2020). Additionally, the American Heart Association (AHA) recommends the DASH diet for the prevention of cardiovascular diseases and other chronic conditions (Kawamura et al., 2016).

Reducing red meat consumption, decreasing total and saturated fat intake, and increasing fruit and vegetable consumption in the DASH diet help reduce its environmental impact (Reynolds et al., 2014). Using data from the EPIC Norfolk cohort study in the United Kingdom, the contribution of the DASH diet model to greenhouse gas emissions was evaluated (Perignon et al., 2016). The group with high adherence to the DASH diet contributed 16% less to greenhouse gas emissions compared to individuals with low diet adherence. The DASH diet has lower greenhouse gas emissions partly because it includes a reduced intake of sugar. This is particularly due to the diet's very low carbon footprint when measuring the amount of sugar per unit of energy (Macdiarmid et al., 2012). One of the most significant changes to make diets more sustainable is to reduce the amount of meat included in the diet.

However, the choice of meat substitutes is crucial (Perignon et al., 2016). In fact, current evidence shows that a diet with low red meat and high fruit and vegetable content has a lower environmental impact. However, in some cases, an increase in the number of fruits, vegetables, and grains consumed to replace animal proteins can have a similar environmental impact (Monsivais et al., 2015). This is because the source, production method, location of production, and amount consumed of the recommended foods replacing meat are key determinants of greenhouse gas emissions, which in turn affect the diet's sustainability. Additionally, removing meat from the diet can lead to nutrient deficiencies, which may negatively impact diet quality. In such cases, it is essential to consider both the nutritional content and sustainability of the foods recommended to replace meat (Perignon et al., 2016). In the study conducted by Monsivais and colleagues, it was found that higher adherence to DASH diet recommendations results in lower greenhouse gas emissions compared to lower adherence diets, and this is attributed to the DASH diet containing less red and processed meat (Monsivais et al., 2015). Other significant and common environmental impact indicators include land use and water use. Land use by humans negatively affects atmospheric greenhouse gas levels, ecosystems, and water quality. Water use is complex. Both irrigation for agriculture and consumption by animals involve high water withdrawal and consumption. As a result, it may be necessary to limit the amount of water available for other purposes (Water Footprint Calculator, 2020). The DASH diet may be a suitable option as it promotes the consumption of protein-rich foods that are diverse and environmentally less demanding in terms of greenhouse gas emissions and land use. However, it has been observed that a more comprehensive investigation is needed regarding the environmental impacts of the DASH diet (Kling et al., 2023).

2.6. Double Pyramid Model

In 2019, the Barilla Center for Food and Nutrition Foundation in Italy introduced an innovative approach to the Mediterranean diet pyramid by incorporating an inverted pyramid that evaluates the ecological impact of food choices (Olgun et al. 2022). This dietary model addresses the impact of food choices on both human health and environmental health. It is a model in which an inverted second pyramid, assessing the ecological impact of foods, is added to the Mediterranean diet model, which is recognized by the FAO as a primary example of sustainable dietary models (Burlingame and Dernini, 2011). While the original pyramid offers Mediterranean-style dietary recommendations, the additional pyramid classifies foods based on their negative environmental impacts by considering their ecological footprint (Can et al. 2021; Kadıoğlu and Sökülmez-Kaya, 2022). In the Environmental Pyramid, the Ecological Footprint is used as a reference to better reflect multiple environmental impacts. In the Double Pyramid Model, foods recommended for higher consumption have a lower environmental impact, while foods recommended for lower consumption have a higher environmental impact (FAO & Bioversity International, 2012). At the base of the food pyramid, which includes foods recommended for higher consumption, are fruits and vegetables, grains, legumes, and olive oil, while at the top, which provides for foods recommended for lower consumption, are sugary foods, sweets, red meat, and saturated fats. This pyramid consists of foods that are healthy, economical, culturally appropriate, and have a low environmental impact. At the base of the environmental pyramid are foods with lower environmental impact, while at the top are foods with higher environmental impact (Akay, 2020). The Double Pyramid Model illustrates the inverse relationship between recommended foods and their environmental impacts. The pyramid specifically demonstrates that vegetable and plant-based diets have a low environmental impact (Ruini et al., 2015). Additionally, a study conducted by Barilla staff concluded that the Double

Pyramid Model promotes sustainability and could serve as an example of sustainable dietary models (Atar, 2021). The Double Pyramid Model highlights the inverse relationship between recommended foods and their environmental impacts, specifically showing that vegetable and plant-based diets have a low environmental impact.

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2.7. EAT-Lancet Commission Reference Diet (Planetary Health Diet)

In 2019, the EAT-Lancet Commission proposed a "Planetary Health Diet" model that supports healthy eating and environmental sustainability, is adaptable to local diets, and is globally applicable. In the Planetary Health Diet model, half of the plate consists of vegetables and fruits, while the other half includes whole grains, unsaturated plant-based oils, plant protein sources, and limited amounts of meat, dairy products, added sugars, and starchy vegetables (Willett et al., 2019). This diet model suggests that global consumption of fruits, vegetables, and whole grains should be doubled, while global consumption of foods like red meat and added sugars should be reduced by 50%. The Planetary Health Diet is open to cultural interpretations, being flexible and universally applicable (Willett et al., 2019).

This dietary model emphasizes both human health and environmental sustainability. The Planetary Health Diet is positively correlated with increased fiber intake and negatively correlated with greenhouse gas emissions and land use (Vega et al., 2018). The Planetary Health Diet aims to feed 10 billion people, prevent 11 million deaths annually from hunger and malnutrition-related diseases, minimize greenhouse gas emissions, prevent the extinction of any species, and protect water and other natural resources (Willett et al., 2019). The Planetary Health Diet is described as a win-win diet, combining scientific goals for healthy diets and sustainable food systems to achieve both health and environmental sustainability (Willett et al., 2019).

The EAT-Lancet Commission estimates that the reference diet could prevent approximately 11 million deaths annually, which is equivalent to 19-24% of global deaths, based on projections derived from aggregate data (EAT-Lancet Commission). A study using data from the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort estimated that adopting different levels of adherence to the EAT-Lancet reference diet could prevent between 19% and 63% of deaths and between 10% and 39% of cancer cases over a 20-year risk period. Additionally, transitioning from low to high adherence to the diet has been reported to reduce food-related greenhouse gas emissions by up to 50% and land use by up to 62% (Laine et al., 2021).

3. ALTERNATIVE FOOD SOURCES

3.1. Edible Insects

The consumption of insects as a food source is called "entomophagy" (Kaldırım and Keser, 2023). Currently, of the 915,000 known insect species worldwide, approximately 40% belong to the order Coleoptera (387,000 species), 16-17% to Lepidoptera (157,000 species), 13-14% to Hymenoptera (117,000 species), 10% to Diptera (155,000 species), 10% to Hemiptera (104,000 species), 5% to Orthoptera (24,000 species), and the remaining 5% to other orders (Capinera, 2010; Stork, 2018). Particularly, species of the order Coleoptera play a significant role in the diets of some mammalian wildlife (Ünal and Arslan 2020). Currently, the commercially produced edible insects include six species: cricket (Acheta domesticus), honey bee (Apis mellifera), domestic silkworm (Bombyx mori), mopane caterpillar (Imbrasia belina), African palm weevil (Rhynchoporus phoenicis), and yellow mealworm (Tenebrio molitor) (Tang et al., 2019).

To meet the food demand of the rapidly increasing global population, world food production needs to increase by 60% (FAO, 2009). The current structure of global agriculture requires 11% of the world's land area and 70% of its potable water (UNESCO, 2014). However, increasing food production by 60% would result in a decrease in potable water resources. In addition to traditional agriculture, food production from livestock accounts for 37% of methane gas emissions. This gas harms natural ecosystems (Goodland and Anhang, 2009). The Food and Agriculture Organization encourages the consumption of insects. This is because insects are a high-quality source of protein and are rich in minerals such as iron and zinc (Kaldırım and Keser, 2023). Additionally, insect farming requires minimal land area and produces lower ammonia emissions and greenhouse gases compared to livestock farming (Gencal and Selçuk, 2024). For these reasons, sustainability is also a key factor in the search for alternative food sources (Gencal and Selçuk, 2024). Insects have a smaller ecological footprint compared to larger livestock, as they consume less feed and have a lower environmental impact (Van Huis et al., 2013). On the other hand, the UN has stated in a report that the global population could reach 8.5 billion by 2030 and 9.7 billion by 2050 (UN, World Population Prospects, 2019). In this context, the FAO of the United Nations foresees the consumption of insects as an alternative food source to address these concerns about human nutrition (Gahukar, 2011). Contrary to popular belief, insects are not just foods bought to try different tastes or consumed only during times of scarcity. On the contrary, insects are used in national diets and dietary programs in many countries (Anankware et al., 2015). With the growing interest in edible insects, the insect industry is advancing (Aydoğan, 2021). The industrial production of insects offers numerous environmental benefits, including reduced land and water use, lower greenhouse gas emissions, and higher feed conversion efficiency (Mishyna et al., 2021; Güneş, 2018).

Edible insects are noted for their rich content in protein and fat, as well as being highly abundant in amino acids, vitamins, and trace elements (Mitsuhashi, 2017). Insects are considered an alternative to animal foods such as red and white meat. In fact, as an alternative food source, insects have a richer and higher-quality content of iron, calcium, and protein compared to other meats (Anankware et al., 2015). Additionally, insect proteins meet the essential amino acid requirements set by the WHO and are more digestible than plant-based proteins, although they are less digestible compared to animal-based proteins (Gravel and Challenges, 2020).

The nutritional properties of edible insects need to be comprehensively investigated and evaluated in terms of their suitability for human consumption (Onwezen et al., 2021). Factors influencing the nutrient composition of insects include species, life stage, diet, gender, developmental environment, methods of inactivation/killing, and processing techniques (Meyer-Rochow et al., 2021; Oonincx and Finke, 2021). Studies show that the protein content in 100 grams of edible insects ranges from 7% to 48%, whereas in beef, it ranges from 19% to 26% (Candoğan and Özdemir, 2021). Moreover, the most abundant amino acids in edible insects are isoleucine, leucine, lysine, phenylalanine, threonine, valine, arginine, histidine, and tyrosine. Essential amino acids constitute 10-30% of the total amino acid composition in edible insects (Candoğan and Özdemir, 2021; Oghenesuvwe and Paul, 2019). Sriprablom et al. (2022) aimed to enrich the nutritional content and enhance the functional properties of cookies by using flours made from T. molitor and Z. atratus (mealworms). In cookies containing 30% T. molitor flour, the protein content increased by 56.7%, and in cookies containing 30% Z. atratus flour, it increased by 58.7%. However, the digestibility of these proteins is crucial for their usefulness in the human diet (Ignaczak and Kowalska, 2021). After protein, lipids are the second most important nutrient component in edible insects (%1,5-77) (Aguilar, 2021). The fatty acids in insects generally resemble those found in animal and plant-based oils (Tekiner et al., 2022). In general, insects are rich in oleic, linoleic, linolenic, and palmitic acids, with their total fat content ranging from 2% to 62%. Cholesterol is the most abundant sterol found in insects (Demirci and Yetim, 2021). In terrestrial edible insects, long-chain polyunsaturated fatty acids, particularly omega-6 fatty acids, are higher compared to those found in aquatic insects (Lange and Nakamura, 2021a). Insects are a good source of vitamins and micronutrients (Tekiner et al., 2022). However, some studies suggest that the content of vitamins and micronutrients in insects may be influenced by their diet (Tang et al., 2019). Edible insects contain various micronutrients, including iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, and zinc. However, the levels of these micronutrients vary depending on the species of the insect (Tang et al., 2019). Crickets and termites contain high levels of iron and zinc. Grasshoppers and mealworms have higher levels of copper, magnesium, manganese, and zinc compared to beef (Lange and Nakamura, 2021b). In a study comparing the nutritional value of edible insects and meat based on their mineral content, it was found that, regardless of species and development stage, insects have higher levels of calcium, zinc, copper, and manganese than meat (Orkusz, 2021).

Chitin and its deacetylated form, chitosan, found in insects, can potentially be considered functional food components with beneficial effects on wound healing, colon and cardiovascular health, cholesterol levels, and both innate and adaptive immune responses (Lange and Nakamura, 2021a). It has been reported that chitin and chitosan, abundant in crickets, support the immune system by suppressing pathogenic microorganisms in the intestines, and this property is attributed to their prebiotic effects (Baş-Aksoy and Nehir, 2021). However, some edible insect populations are under threat of extinction due to anthropogenic factors. Human collection of insects can lead to direct competition with other predators. This situation can negatively affect population viability. Various edible insect species serve as hosts or prey for other insects, as well as birds, fish, amphibians, reptiles, and mammals. Therefore, collecting edible insects from the wild instead of farming them can pose a threat to the provision and balance of essential ecosystem services (Lange and Nakamura, 2021a).

3.2. Artificial Meat

The increase in prosperity parallel to population growth not only imposes a burden on natural resources and ecosystems but also necessitates the development of alternative food sources. As traditional meat production systems are no longer sustainable, scientists are researching alternative protein sources (Okur et al., 2023). Consequently, there is an ongoing search for new protein alternatives, primarily focusing on replacing animal-based foods, particularly meat production (Sürek and Uzun, 2020). In our current era, one of the solutions identified for this protein alternative is artificial meat (Ünver et al., 2018). Known as in vitro meat, artificial meat is a product produced using cell culture technology from stem cells derived from skeletal muscle isolated from farm animals, typically through muscle biopsies (Okur et al. 2023). Artificial meat is presented by its advocates as a sustainable alternative for consumers who want to be more environmentally responsible but are unwilling to change the composition of their diets (Chriki and Hocquette 2020). Although artificial meat is primarily discussed in the context of veganism, its rise is also driven by concerns that conventional animal farming significantly contributes to greenhouse gas emissions and that high meat consumption is linked to cancer and cardiovascular diseases (Laestadius and Caldwell 2015; Ireland, 2019). Ruminant animals, in particular, have a significant impact on greenhouse gas emissions. Of the greenhouse gases produced by these animals, 44% originates from enteric fermentation in their intestines, 41% from their diet, 10% from manure management, and 5% from energy expenditures (FAO, 2019). It is argued that the production of artificial meat could help reduce greenhouse gas emissions and contribute to mitigating global warming. Additionally, artificial meat production is expected to significantly reduce the number of animals slaughtered for protein, thereby improving animal welfare and eliminating the need for their feeding and slaughter (Hocquette, 2016). Artificial meat producers claim that meat produced in a controlled environment can reduce the risk of foodborne pathogens, leading to healthier and safer meat production. Additionally, it is believed that artificial meat, with its customizable composition, could help prevent various diseases associated with meat consumption, such as cardiovascular diseases, diabetes, and colon cancer (Hong et al., 2021). On the other hand, concerns have been raised that artificial meat might pose negative effects on food safety. Although it is claimed that artificial meat, being produced without animals, will not harbor microorganisms, there is a risk that extensive cell proliferation could potentially also propagate cancerous cells. Additionally, it has not been definitively established that the chemicals required for cell culture do not pose risks to food safety (Hocquette, 2016).

The main methods of artificial meat production include cell culture, tissue culture techniques, 3D printing, and other emerging methods (Okur et al., 2023). Depending on the production method, artificial meat can be classified into plant-based meat alternatives and cultured meat (McClements, 2020; Mateti et al., 2022). Artificial meat consists of edible mature muscle cells and subsequently developed larger muscle tissues, derived from the stem cells of animals raised for food production (Sürek and Uzun, 2020; Bhat et al., 2015). These synthetic meats are produced using in vitro methods (Tiberius et al., 2019; Bhat et al., 2017) and are obtained through technologies applied to transform stem cells into fat and muscle cells (Post, 2014). Despite this, the produced meat does not fully resemble real muscle tissue in terms of fat cells, connective tissue, blood vessels, fibers, and nerves (Hocquette, 2016). Meat's rich composition includes muscle, fat, blood, nerve, and connective tissues. To replicate these, culturing myoblasts, fibroblasts, and adipocytes is essential. Artificial meat lacks blood and faces limited nutrient and oxygen diffusion, restricting cell layer production. Myoglobin gives meat its red color, but cultured muscle tissues are usually pale due to its absence. Adding myoglobin directly to the culture medium can enhance its content in cultured cells (Okur et al., 2023). Additionally, the use of alternative colorants is also being considered (Post and Hocquette, 2017). The fatty acid composition in meat affects its dietary value. The addition of fatty acids to artificial meat is feasible through the co-culture of adipocytes, derived from adipose stem cells that can synthesize various saturated and unsaturated fatty acids. However, essential fatty acids and other nutritionally valuable compounds found in meat may be lacking in the co-culture approach (Okur et al., 2023). Meats contain a significant portion of various B vitamins, including vitamin B12. If artificial meat is to serve as an alternative to traditional meat, its vitamin B12 content needs to be taken into account. Because vitamin B12 is found only in animal sources (Hunt et al., 2014). Additionally, the absorption of vitamin B12 requires a binding protein (transcobalamin II) that facilitates its transport across the cell membrane (Okur et al., 2023). The nutritional values of artificial meat are not yet fully understood. The macro and micronutrient content of artificial meat can vary depending on the production process and the additives used (Okur et al., 2023). The provision of desired nutrients in synthetic meat production has not yet been fully clarified. Excessive amounts of added minerals or other nutrients could potentially turn synthetic meat into a chemically altered food product (Hamdan et al., 2018; Costa et al., 2020). In synthetic meat production, while cell proliferation is managed, complete control may not always be in the hands of the producers (Muslu, 2022). If control conditions during meat production are not well maintained, there is a risk of the formation of structures such as cancer cells. This risk could pose health concerns (Hocquette, 2016). Additionally, currently produced synthetic meats do not yet match traditional meat in terms of flavor, quality, taste, and aroma (Zhang et al., 2020). In traditional meat production, tissues such as muscle, fat, and nerves contribute to the meat's unique aroma, texture, and flavor. In artificial meat production, a complete replication of traditional meat tissue has not yet been achieved (Muslu, 2021). Therefore, it is not yet capable of fully replacing traditional meat in terms of taste (Zhang et al., 2020). Another discussion topic regarding artificial meat is the consumer perception of its naturalness and ethical considerations, despite its accepted benefits for food safety and environmental sustainability (Choudhury et al., 2020). In traditional meat production, factors such as land use, soil erosion, water resources, natural resource depletion, energy consumption, animal suffering, and production time are considered disadvantages compared to artificial meat. Conversely, production cost, variety, and consumer acceptance are often cited as advantages of traditional meat (Bhat et al., 2019).

3.3. Edible Algae

Algae are cellular factories that convert carbon dioxide into potential biofuels, foods, feed, and high-value bioactive compounds, utilizing sunlight in the process (Paul Abishek et al., 2014). Algae, which make up approximately 90-95% of marine flora and can easily grow in a wide range of aquatic environments, are organisms that also produce nutrients through photosynthesis (El-Sheekh et al., 2006). Through their photosynthetic pigments, algae can convert

CO_2 and H_2O into complex carbohydrates, which not only increases the nutrient content in their aquatic environment but also raises the dissolved O_2 levels in the water (Oğur, 2016).

Humans can consume nearly 160 different types of algae. In East Asian countries like China, Korea, and Japan, algae are considered a significant future alternative to address food security and hunger threats (Ünver Alçay et al., 2017). However, due to their ability to absorb toxic organic compounds and heavy metals, algae do not cause secondary contamination. As a result, algae can also be used in wastewater treatment (Abdel-Raouf et al., 2012).

Algae are a heterogeneous group of organisms commonly classified into microalgae (phytoplankton) and macroalgae (seaweeds and filamentous algae) based on their size (Abubakar et al., 2012; Leal et al., 2013). Microalgae include both single-celled and simple multicellular microorganisms (Paul Abishek et al., 2014). Macroalgae are classified based on their pigmentation into three groups: brown algae (Phaeophyceae), green algae (Chlorophyceae), and red algae (Rhodophyceae) (Demirbas and Demirbas 2011; Leal et al., 2013). Microalgae contain high amounts of lipids (20-80%), protein (39-71%), and dietary fiber (up to 74.6% in some species) in their dry matter (Şirinyıldız and Yorulmaz 2022). They are considered an additional source of nutrients due to their carotenoids, carbohydrates, sterols, vitamins, pigments, and polyunsaturated fatty acids (Şirinyıldız and Yorulmaz, 2022), particularly ω-3 fatty acids (Balasubramanian et al., 2011; Akyıl et al., 2016). These organisms, which are often microscopic in size, can grow rapidly in the presence of carbon dioxide (Paul-Abishek et al., 2014; Demirbas and Demirbas, 2011). Macroalgae are multicellular plants that grow in either salty or fresh water (Demirbas and Demirbas, 2011). Macroalgae, also known as seaweeds, exhibit a complex and dynamic classification. Brown algae, in particular, are found in significant quantities in temperate marine regions (Şirinyıldız and Yorulmaz, 2022). These algae have applications in the food, pharmaceutical, and cosmetic industries (Pereira et al., 2017). Over a hundred types of algae can be consumed as food due to their macro and micronutrient content. Some seaweeds also contain minerals such as iron, copper, zinc, and manganese. Microalgae are an important resource that converts sunlight into chemical energy through carbon dioxide. They utilize a significant portion of their biomass in the production of rich products such as polyunsaturated fatty acids, carotenoids, phycobiliproteins, polysaccharides, and phytotoxins (Raja et al., 2008). The products obtained from this production are frequently used as rich sources of protein in human nutrition, aquaculture, and nutraceuticals (Del-Campo et al., 2007).

The primary factor in evaluating algae as a potential food source is their nutritional composition (Nale, 2021). Some microalgae are characterized as being highly rich in carbohydrates, proteins, fats, and valuable components. Algae are highly rich in ω-3 fatty acids, which have significant importance in nutrition (Pereira et al., 2017). Some algal species are a good option for fatty acid production because they can store high amounts of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The high amounts of EPA and DHA in marine organisms are due to algae being their primary food source (Muslu and Gökçay, 2020). In the study conducted by Eleren and Öner (2019), the carbohydrate, protein, and lipid contents of some algal species were highlighted. Within the scope of the study, the carbohydrate content of different algal species was reported to range from 15% to 77%, the protein content from 44% to 76%, and the lipid content from 23% to 62%. Algae and algal products are rich in vitamin content (Eleren and Öner, 2019). Vitamin production and metabolism can vary according to algal species. This variation is influenced by many factors, particularly environmental conditions (Helliwell et al., 2011; Helliwell et al., 2013). It has been reported that algae are rich in vitamins A, B1, B2, C, and E, as well as minerals such as iodine, potassium, iron, magnesium, and calcium (Becker, 2004). Some algae, such as Saccharina latissima and Laminaria ochroleuca, contain high levels of iodine. Commercial forms sold as seaweed powder are used as sources of iodine. Iodine levels vary widely depending on the species of algae (Muslu and Gökçay, 2020). Macroalgae are potentially rich sources of iron for human diets. It is thought that the iron content among macroalgae species collected from the same regions and at the same time can vary significantly, likely due to differences in metabolic requirements (Cabrita et al., 2016). Additionally, the iron content of algae, while species-specific, also varies seasonally and geographically depending on the metal content of coastal waters (Cabrita et al., 2016; García-Casal et al., 2007).

Algae are an important producer link in the food chain (Nale, 2021). Their use as a food source in Southeast Asia and island nations is increasing the popularity of algae day by day (Ünver-Alçay et al., 2017). Many algae can be commercially produced for use in the food industry. Its most valuable benefits include the ability to be produced in almost any terrain, a shorter production process compared to terrestrial plants, fermentation that is independent of climatic conditions, production using waste products, the development of new strains through recombinant biotechnology applications, and the high production of less common single-cell oils (Sathasivam et al., 2018).

It is believed that using ocean and seawater for algae cultivation could serve as an alternative source for preventing hunger and achieving sustainable nutrition, without utilizing land and minimizing environmental damage (Muslu and Gökçay, 2020). Microalgae are considered a promising and sustainable alternative protein source (Nale, 2021). However, potential allergens, contaminants, and hazardous by-products that may arise during the production of microalgae are aspects that are not yet well understood in terms of food safety (Spiegel et al., 2013).

CONCLUSION

The concept of sustainable nutrition is becoming globally significant due to its numerous positive contributions to the environment. Sustainable nutrition ensures optimal dietary intake by assessing the life cycle of foods and examining their environmental impacts. It involves meeting current needs without compromising the ability of future generations to meet their own nutritional requirements, encompassing economic, social, and environmental objectives. It plays a critical role in maintaining individual health and ensuring environmental sustainability. Studies in the literature explain that sustainable nutrition is characterized by low greenhouse gas emissions and water footprint scores, efficient use of energy and land, and minimal food waste and losses. This dietary approach contributes to both human health and the future of the planet by aiming for the efficient use of resources, reducing food waste, and minimizing environmental pressure. Its key strategies include reducing the environmental footprint of food production, promoting plant-based diets, and minimizing food waste. The focus on sustainability has led to the development of sustainable diets, which aim to balance current nutritional needs with the conservation of resources for future generations.

With the increasing food demand and adverse climate changes, sustainable diet models have become increasingly important. Sustainable nutrition models are typically characterized by plant-based diets that support seasonal and fresh consumption. It is important that these diet models, which are beneficial for both human and environmental health, are also culturally acceptable. Mediterranean Diet, Nordic Diet, DASH Diet, Double Pyramid Model, Flexitarian Diet, EAT-Lancet Commission Reference Diet, Vegetarian and Vegan diets are examples of sustainable nutrition models that include plant-based foods. The implementation of sustainable nutrition models will ensure optimal well-being for human, environmental, and planetary health. Additionally, alternative protein sources play a significant role in promoting sustainable eating habits. Algae, insects, and artificial meat are emerging as notable alternative protein sources. Algae can provide a sustainable source by utilizing ocean and sea waters while minimizing environmental harm. However, the effects of algae on human metabolism are not yet fully understood. Insects stand out as a sustainable source due to their low water requirements, high protein efficiency, and low greenhouse gas emissions, along with their nutritional content. However, scientific research and risk assessments are necessary to ensure their safe consumption. Artificial meat has the potential to reduce environmental harm and provide microbiological safety, but it faces challenges such as production costs and consumer acceptance. The expectation for artificial meat to be safe and affordable will drive advancements in this field.

Promoting sustainable eating habits is crucial for ensuring that future generations can lead healthy and safe lives. Achieving this goal requires a collective effort from individuals, communities, governments, and non-governmental organizations. Promoting a culture of sustainable nutrition will create long-term positive effects both at the individual and global levels. This is not just a lifestyle choice but also a responsibility we owe to our planet and ourselves.

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CONFLICT OF INTEREST STATEMENT

There is no conflict of interest with any institution or person within the scope of the study.

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