



Review Article

Med Diet 4.0: the Mediterranean diet with four sustainable benefits

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Abstract

Objective: To characterize the multiple dimensions and benefits of the Mediterranean diet as a sustainable diet, in order to revitalize this intangible food heritage at the country level; and to develop a multidimensional framework – the Med Diet 4.0 – in which four sustainability benefits of the Mediterranean diet are presented in parallel: major health and nutrition benefits, low environmental impacts and richness in biodiversity, high sociocultural food values, and positive local economic returns.

Design: A narrative review was applied at the country level to highlight the multiple sustainable benefits of the Mediterranean diet into a single multidimensional framework: the Med Diet 4.0.

Setting/subjects: We included studies published in English in peer-reviewed journals that contained data on the characterization of sustainable diets and of the Mediterranean diet. The methodological framework approach was finalized through a series of meetings, workshops and conferences where the framework was presented, discussed and ultimately refined.

Results: The Med Diet 4.0 provides a conceptual multidimensional framework to characterize the Mediterranean diet as a sustainable diet model, by applying principles of sustainability to the Mediterranean diet.

Conclusions: By providing a broader understanding of the many sustainable benefits of the Mediterranean diet, the Med Diet 4.0 can contribute to the revitalization of the Mediterranean diet by improving its current perception not only as a healthy diet but also a sustainable lifestyle model, with country-specific and culturally appropriate variations. It also takes into account the identity and diversity of food cultures and systems, expressed within the notion of the Mediterranean diet, across the Mediterranean region and in other parts of the world. Further multidisciplinary studies are needed for the assessment of the sustainability of the Mediterranean diet to include these new dimensions.

Keywords
Mediterranean diet
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In recent years, within the international debate on sustainability, food security and nutrition^(1,2), sustainable diets have emerged as a challenging public health nutrition issue^(3–7) as well as a critical issue for sustainable food systems^(8–10).

The incorporation of sustainability aspects into dietary guidelines has been increasingly discussed over the past decades to make diets healthier for consumers as well as for the environment. After the publication of the first dietary guidelines for sustainability in 1986⁽¹¹⁾, criticisms have continued to ignite controversial debates, as reported 12 years later⁽¹²⁾. For example, the recent proposals by the US Department of Agriculture Dietary Guidelines Advisory Committee to include sustainability issues into the 2015 Dietary Guidelines for Americans⁽¹³⁾ were met with criticism, largely deemed political, and were ultimately rejected⁽¹⁴⁾. In the meantime, several countries such as Qatar, Brazil, Sweden and the Netherlands have already incorporated sustainability in their national dietary recommendations^(15–18). The German Council for Sustainable Development has produced a 'sustainable shopping basket' to guide consumers to shop for food in a more sustainable way⁽¹⁹⁾.

The degradation of ecosystems and the negative impact in relation to poverty and health are making a compelling case for re-examining food systems and diets within the sustainable development agenda. The concept of sustainable diets acknowledges the interdependencies of food production and consumption with food requirements and nutrient recommendations, and at the same time reaffirms the notion that human health cannot be isolated from that of ecosystems⁽²⁰⁾. Sustainable diets, which are ecosystem-specific, offer a practical way of applying sustainability to food security and nutrition. In this overall context, sustainability becomes the long-term component of all the levels and dimensions of food security – the well-established and accepted determinant of a nation's health and well-being⁽¹⁾. Supporting the implementation of the Post-2015 Sustainable Development Agenda, ending malnutrition in all its forms is an imperative to drive sustainable development⁽²¹⁾.

The FAO has estimated that by 2050, in order to satisfy the needs of a growing and richer world population with increased demand for animal products, food production will have to increase by at least 60%⁽²²⁾. This will be a major challenge for food security and sustainability, considering that natural resources are already increasingly stressed and degraded, with the additional negative effects of climate change. Today, a main concern is to conserve natural resources for future generations while simultaneously providing enough food, in quantity and quality, to meet the nutritional requirements of a growing global population. Radical changes in food production and consumption will be required over the coming decades⁽²³⁾. Therefore, there is an urgent need for transdisciplinary measures to address both undernutrition and overnutrition,

diversify diets, reduce waste and minimize environmental damage⁽²⁴⁾. There is growing scientific evidence on the environmental impacts of diets, linking public health nutrition and sustainability^(24–29), but there are still many challenges in understanding the full complexity of sustainable diets, their assessments and determinants^(30–32).

The Mediterranean diet as a case study for sustainable diets

Within the international debate on a shift towards more sustainable food systems and diets, interest in the Mediterranean diet as a model of a sustainable dietary pattern has increased^(1,20,33). The notion of the Mediterranean diet has undergone a progressive evolution over the past 50 years, from that of a healthy dietary pattern for the heart⁽³⁴⁾ to the model of a sustainable diet^(1,20,35–37). From the early 1990s, taking into account increasing concerns regarding environmental sustainability, the Mediterranean diet as a plant-centred diet began to be researched as a sustainable dietary pattern⁽³⁵⁾, with lower environmental impacts^(25–29).

Despite the fact that the Mediterranean diet is well documented and acknowledged as a healthy diet⁽³⁸⁾, paradoxically, it is being abandoned, mainly by the young generations in most Mediterranean countries⁽³³⁾. Southern and Eastern Mediterranean countries are passing through a 'nutritional transition' in which problems of undernutrition coexist with overweight, obesity and diet-related chronic diseases⁽³⁹⁾. The erosion of the Mediterranean diet heritage, by the loss of its adherence among Mediterranean populations, is alarming as it has undesirable impacts not only on health but also on social, cultural, economic and environmental trends in the Mediterranean region⁽³³⁾.

In 2009, an international conference on 'The Mediterranean Diet as a Sustainable Diet Model' was organized to present the Mediterranean diet as a sustainable dietary pattern; and to update the Mediterranean diet pyramid in the light of current lifestyle changes, with serving sizes based on frugality and local habits, as well as with new characteristic elements such as biodiversity, seasonality, culinary activities, traditional, local and eco-friendly food products, conviviality, adequate rest and regular physical activity^(40,41). As a follow-up in 2010, at an international scientific symposium on 'Biodiversity and Sustainable Diets: United against Hunger', held at the FAO in Rome, an agreement was reached on the following definition of 'sustainable diets'⁽²⁰⁾:

'Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.'

Table 1 Potential indicators for assessing the sustainability of the Mediterranean diet

Thematic area	Proposed indicators
A. Nutrition and health	A1. Diet-related morbidity/mortality A2. Fruit and vegetable consumption/intake A3. Vegetable:animal protein consumption ratio A4. Average dietary energy adequacy A5. Dietary diversity score A6. Dietary energy density score A7. Nutrient density A8. Food biodiversity composition and consumption A9. Nutritional anthropometry A10. Physical activity/physical inactivity prevalence A11. Adherence to the Mediterranean dietary pattern A12. Rate of local/regional foods and seasonality A13. Rate of eco-friendly food production and/or consumption
B. Environment	B1. Water footprint B2. Carbon footprint B3. Nitrogen footprint B4. Biodiversity
C. Economy	C1. Food consumer price index (FCPI): cereals, fruit, vegetables, fish and meat C2. Cost of living index (COLI) related to food expenditures: cereals, fruit, vegetables, fish and meat C3. Distribution of household expenditure per groups: food C4. Food self-sufficiency: cereals, fruit and vegetables C5. Intermediate consumption in the agricultural sector: nitrogen fertilizers C6. Food losses and waste
D. Society and culture	D1. Proportion of meals consumed outside home D2. Proportion of already prepared meals D3. Consumption of traditional products (e.g. proportion of product under PDO or similar recognized traditional foods) D4. Proportion of mass media initiatives dedicated to the knowledge of food background cultural value

PDO, Protected Designation of Origin.

On this occasion, an entire session was devoted to the Mediterranean diet, as a model of sustainable diet⁽²⁰⁾. In 2011, the FAO and the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) started a joint collaboration for assessing the sustainability of the Mediterranean diet as a case study towards the improvement of Mediterranean sustainable food systems⁽⁴²⁾. In 2012, at the ninth CIHEAM meeting of the Ministers of Agriculture in Malta, this led to the acknowledgement of the role of the Mediterranean diet as 'a driver of sustainable food systems in the Mediterranean'⁽⁴²⁾. From 2011 to 2015, through a series of international workshops and meetings, a methodological approach was developed and a first ensemble of potential indicators to assess the sustainability of the Mediterranean diet was identified, as reported in Table 1^(42–44). Each indicator's information has been detailed concerning definition, methodology, background, data sources, limitations of the indicator and references^(42,44).

Each of these indicators requires appropriate data, not all presently available at country level, to evaluate interactions and correlations between the various indicators as well as intra- and inter-dimension weightings necessary for the future development of a composite index.

Development of the Med Diet 4.0 framework

The Med Diet 4.0 framework was developed between 2014 and 2015 as a follow-up of these previous efforts and

further implemented by 'longstanding' collaborations among the co-authors as members of the scientific committee of the International Foundation of Mediterranean Diet (IFMeD). In keeping with the 2010 agreed definition of 'sustainable diets'⁽²⁰⁾, and in continuation of previous studies on the characterization of the Mediterranean diet as a sustainable diet model^(20,35,36) and on its sustainability assessment^(42,43), the following four sustainable benefits of the Mediterranean diet were highlighted and incorporated into one single comprehensive Med Diet 4.0 framework: (i) major health and nutrition benefits; (ii) low environmental impacts and richness in biodiversity; (iii) high sociocultural food values; and (iv) positive local economic returns. By taking into account the diversity of Mediterranean food cultures and systems, expressed within the notion of the Mediterranean diet, the conceptual multidimensional framework of the Med Diet 4.0 was conceived to allow appropriate country-specific variations, as exemplified in Fig. 1.

The Mediterranean diet is a highly diversified heritage, in which food cultures and systems vary from country to country. Although different they may be considered as variants of a basic Mediterranean dietary pattern⁽⁴⁵⁾. No attempts were made to cover systematically all sustainability assessment issues of the Mediterranean diet. A narrative review was applied to allow for incorporating together, within the multidimensional framework of the Med Diet 4.0, the four identified sustainable benefits of the Mediterranean diet.

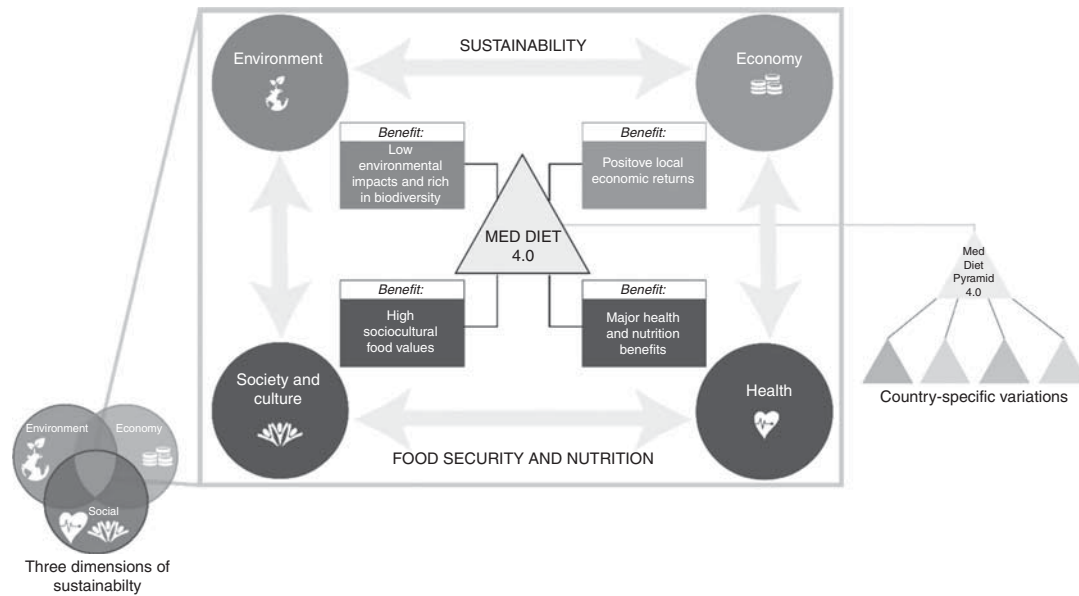


Fig. 1 The Med Diet 4.0 framework that applies the principles of sustainability to the four sustainable dimensions of the Mediterranean diet

First benefit: Major health and nutrition benefits

Since the pioneer Seven Countries Study by Keys⁽³⁴⁾, much scientific evidence has highlighted the protective effect of the Mediterranean diet on CVD and its health benefits in preventing a number of chronic and degenerative diseases^(46–55). Data from a series of cohort and case–control studies have shown that a high intake of foods typical of the traditional Mediterranean diet pattern (MDP) is associated with a reduced risk for developing various types of cancers, including upper digestive tract, stomach, colorectal, pancreas, liver, and selected hormone-related cancers such as endometrial cancer^(56–60).

In support of all these diet–health connections, recent studies have clearly underlined the nutritional quality of an MDP. Persons who adhere closely to an MDP fulfil their micronutrient requirements much better than persons on a typical Western diet^(61,62). Computer-assisted modelling of individual diets identified that the most important foods that enable people to fulfil nutritional requirements (except for vitamin D) are those characteristic of the MDP⁽⁶³⁾. Surveys have repeatedly shown that adherence to an MDP is also associated with a healthier body weight^(64,65), reduced waist circumference as a marker of central obesity⁽⁶⁶⁾, and lower incidence of the metabolic syndrome⁽⁶⁷⁾ and type 2 diabetes^(68,69). The Mediterranean diet may positively influence the ageing process⁽⁷⁰⁾ by delaying the evolution of cognitive decline linked to Alzheimer’s disease⁽⁷¹⁾ and vascular dementia, which is often documented a long time before the clinical diagnosis of dementia⁽⁷²⁾. The Mediterranean diet appears to have numerous other health advantages that are still under study, such as lower peripheral artery disease⁽⁷³⁾, decreased inflammation and improved endothelial function⁽⁷⁴⁾,

improved respiratory fitness⁽⁷⁵⁾ and immunity⁽⁷⁶⁾, decreased mental disorders such as depression⁽⁷⁷⁾, as well as improved quality of life⁽⁷⁸⁾. This substantial body of scientific evidence links the Mediterranean diet to the prevention of the main chronic non-communicable diseases. Considering the increasing global trends in overweight and obesity and the finding that most deaths attributable to overweight and obesity are cardiovascular deaths⁽⁷⁹⁾, the adoption of an MDP can be an important cost-effective health-care measure development strategy⁽⁸⁰⁾.

Second benefit: Lower environmental impacts and richness in biodiversity

Many studies have shown that the Mediterranean diet has a lower environmental impact than other dietary patterns. This is because it is mainly a plant-based diet with low consumption of animal products and thus has a smaller water footprint and lower greenhouse gas emissions, compared with other current dietary patterns^(25–29). Increased adherence of the Spanish population to the MDP was reported to have a marked impact on all standard environmental footprints: reduce greenhouse gas emissions, land use and energy consumption, and to a lower extent water consumption, while on the contrary, adherence to a Western dietary pattern increases all these parameters⁽⁸¹⁾. In an Italian study, adherence to the MDP was shown to significantly reduce the food environmental footprint on natural resources especially for water consumption⁽⁸²⁾. The Mediterranean basin has long been identified as a ‘hotspot’ of biodiversity, an area featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat⁽⁸³⁾. The loss of indigenous knowledge on the use of local crops in favour



of a small number of non-native species and varieties has affected traditional food production systems and biodiversity across the Mediterranean area⁽⁸⁴⁾. The Mediterranean diet encourages the use of a wide range of cereals, fruits and vegetables, not only cultivated products but also wild species, thus sustaining them together with the local, indigenous and traditional knowledge about their use. Therefore, safeguarding and promoting the Mediterranean diet is of paramount importance for the conservation of the extraordinarily rich biological diversity in the region and vice versa⁽⁸⁵⁾. The seasonal consumption of fresh and local products, biodiversity, variety of foods (especially fruits and vegetables of different colours), traditional culinary activities, conviviality and frugality represent the cornerstone of conserving the Mediterranean diet heritage⁽⁸⁶⁾.

Third benefit: High sociocultural food value

In 2010, the United Nations Educational, Scientific and Cultural Organization acknowledged the Mediterranean diet as an Intangible Cultural Heritage of Humanity, described as follows⁽⁸⁷⁾:

'The Mediterranean Diet, from the Greek word 'diáita' 'diet' means 'way of life–lifestyle', a set of skills, knowledge, rituals, symbols and traditions, ranging from the landscape to the table. Eating together is the foundation of the cultural identity and continuity of communities throughout the Mediterranean basin. The Mediterranean diet emphasizes values of hospitality, neighbourliness, intercultural dialogue and creativity, and a way of life guided by respect for diversity.'

Frugality as an overarching principle of the Mediterranean diet expresses the care in food preparation, moderation in portion size and avoiding waste, and is linked to the high cultural, social and economic value that food has for all Mediterranean peoples⁽⁸⁸⁾. In the Mediterranean cultures, eating is important over and above the physiological need for energy⁽⁸⁹⁾. Family and communal meals are a moment of conviviality and importance, as well as fun and pleasure (more or less explicit), and represent a daily opportunity for social exchange and communication. The Mediterranean diet is a sociocultural historical heritage intimately linked to the lifestyles of the Mediterranean peoples throughout their history, with a myriad of food traditions, religious and cultural differences, and the succession of different dominant civilizations⁽⁹⁰⁾. The Mediterranean diet is an expression of the diversity of Mediterranean food cultures, acknowledged as equivalent to the Mediterranean cultural food systems or Mediterranean culinary systems⁽⁹¹⁾. Thus, the Mediterranean diet is a complex web of sociocultural aspects, and must always be considered as an integral part of interdependent Mediterranean food system(s) and never as an independent entity⁽⁹¹⁾. Consumption, as part of the Mediterranean diet,

cannot be separated from production or social and cultural factors that have built historically around food in the Mediterranean region. The Mediterranean diet is a concept that embraces biodiversity, sustainability, quality, palatability, health and cultural heritage. Safeguarding the Mediterranean diet should be the driving force behind responsible, local and sustainable consumption, as a model of a sustainable development^(92,93). The Mediterranean diet, with its characteristic intra- and inter-cultural social similarities and distinctions, encourages mutual awareness and understanding. The Mediterranean diet is an example, at the local, national and international levels, of mutual multicultural appreciation mediated through the culinary and social value of food.

Fourth benefit: Positive local economic returns

The Mediterranean diet, as a system that respects local specificities, ensures the conservation and development of traditional activities and crafts, thereby guaranteeing the balance between the territory and the people⁽⁸⁴⁾. Whereas the 'fame' of the Mediterranean diet is well established in industrialized countries⁽⁹⁴⁾, it is still hardly known in parts of the Mediterranean region, especially in Southern and Eastern countries⁽³⁹⁾. The existing worldwide media recognition of the Mediterranean diet as a healthy diet could be used as a leverage tool for a very effective marketing campaign for the promotion of the Mediterranean foods associated with the Mediterranean diet, in order to drive positive economic returns locally⁽⁹⁵⁾. Thus, the Mediterranean diet may become a catalyst for sustainable development of Mediterranean small rural areas, especially through the valorization of typical and traditional Mediterranean food products⁽⁹⁶⁾. Particularly for North African and Near East countries, a greater adherence to the MDP could produce economic benefits by reducing their very heavy dependence on agricultural and food imports⁽⁹⁷⁾. This requires the valorization of local food products and empowerment of their producers; improved transparency and protection of the traditional and typical Mediterranean food products, through geographic labelling, quality standards and product origin identification⁽⁹⁶⁾, as well as combining tradition, innovation and sustainability⁽⁹⁸⁾. Promoting the Mediterranean diet by highlighting the frugality that is at its core, as a traditionally 'food-saving culture', can contribute to reducing the amount of food wasted⁽⁹⁹⁾.

Discussion

The Med Diet 4.0 framework can have a very important educational and communicational role towards the revitalization of the Mediterranean diet. In the Mediterranean, there is widespread awareness of the social, cultural, economic and health aspects of 'food', and this is shared by all Mediterranean people. However, the current



perception of the Mediterranean diet is mostly related to a balanced quantity of nutrients, which is graphically represented in a food pyramid^(41,46), rather than as a direct expression of the Mediterranean lifestyle, a way of living everyday life. Therefore, the Med Diet 4.0 framework provides an innovative multidimensional approach for communicating the multiple sustainable benefits of the Mediterranean diet. It can contribute to the development of multidisciplinary studies for the assessment of the sustainability of the Mediterranean diet, at the country level, to improve adherence among Mediterranean populations. Yet, effective functioning of the framework requires that discrepancies in how the Mediterranean diet has been defined and assessed are resolved^(100,101). More interdisciplinary studies on the interdependencies among the four dimensions and how their benefits are linked are required to apply the Med Diet 4.0 framework at the country level. The interdependencies and synergies among the four sustainability dimensions and related mutual benefits of the Mediterranean diet, identified and pointed out within the Med Diet 4.0 framework, need to be further clarified, particularly at the country level or more specifically at the ecosystem level, as they are very diverse across the Mediterranean. In particular, there is a need for more studies on the diet's sociocultural and economic sustainability. The new approach of the Med Diet 4.0 can contribute to a better understanding of sustainable diets and their characterization within different food systems and cultures, with specific regard to the Mediterranean region and the sustainability of dietary patterns in different world contexts. Diets are at the intersection of extremely diverse scientific disciplines, from anthropology to nutrition, from agro-sciences to sociology, from health to ecology, from culinary skills to lifestyle management. This requires not only a huge amount of harmonized data but also agreed methodologies, analytical tools for indicators and clarity regarding the context and the scope of the study⁽⁸⁾. Improving the understanding between production and consumption could improve the assessment of the contribution of the Mediterranean diet to the sustainability of a specific Mediterranean country's food system. Most diets are no longer determined by what is locally produced, as it was for traditional food systems. There is an increased disconnection between the place of production and the space of consumption. The links between a diet and a geographic area have loosened with globalization⁽⁸⁾. A better understanding of these relationships and their dynamics could also be key to recognizing drivers of change, including potential means to improve the sustainability of diets and food systems⁽⁸⁾. The multidimensional framework of the Med Diet 4.0 can provide the ground for a better understanding of these associations, within a specific country context, towards the improvement of the sustainability of food consumption patterns and diets. To understand further how to assess the

sustainability of the Mediterranean diet, within the context of the diversity of Mediterranean food systems, more interdisciplinary collaborations are needed as well as more cooperation among governments, academia, researchers, private sector, civil society and the mass media. In the Mediterranean, 'food' is a strategic meeting place of dialogue and exchange, which is very important for the cultural, social and economic value it has in each Mediterranean country. The Mediterranean diet is understood as a common way of life, yet one in continuing evolution, a complex system of shared knowledge related to food, culture and people, a result of a particular environmental, historically multifaceted geographic region: the Mediterranean.

Until recently, the perception of the Mediterranean diet solely as a 'healthy' diet has overshadowed other important sociocultural, economic and environmental benefits linked to the Mediterranean diet heritage. Therefore, it is now necessary to enhance the Mediterranean diet as a sustainable diet as well as a sustainable lifestyle which is grounded in the cultural identities of Mediterranean people and better adapted to present times and different population groups and life stages: a contemporary eating culture which also includes the idea of sustainability⁽³⁷⁾. The Med Diet 4.0 framework, by highlighting its several sustainable benefits, can contribute to increasing the effectiveness of the Mediterranean diet as an educational model for nutrition and health promotion⁽¹⁰²⁾, which should be critically reviewed and assessed in its sustainability and strengthened through the development of new national school curricula in the Mediterranean region. These curricula should be implemented to foster more responsible food choices in adherence to the Mediterranean sustainable diet model. They should provide sessions to build competences such as Mediterranean-style cooking skills, taste-testing, school food gardens and food basket planning, ideally involving the families and communities of participating children. There is a need to advocate for such sustainable food and nutrition education with both policy makers and the general public, highlighting the holistic benefits of the Mediterranean diet, 'from the hearth to the earth'⁽¹⁰³⁾. The Med Diet 4.0 approach can facilitate a reappropriation by the young Mediterranean generations of their dietary cultural heritage by better understanding the way they are eating and how it is related to their own health as well as to the sustainability of the planet.

Conclusions

The Med Diet 4.0 framework provides a multidimensional and interdisciplinary approach to characterize the Mediterranean diet as a sustainable diet, in the context of Mediterranean sustainable food systems. It contributes to modifying the current limited perception of the Mediterranean diet by moving from a healthy diet towards a sustainable lifestyle model, with country-specific and



culturally appropriate variations. It also takes into account the identity and diversity of food cultures and systems, expressed within the notion of the Mediterranean diet, across the Mediterranean region and in other parts of the world. Further multidisciplinary studies are needed for the assessment of the sustainability of the Mediterranean diet with these specific variations. By providing a broader understanding of its several sustainable benefits, the Med Diet 4.0 can play a very important educational and communication role towards the revitalization of the Mediterranean diet.

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References

- Berry EM, Dernini S, Burlingame B *et al.* (2015) Food security and sustainability: can one exist without the other? *Public Health Nutr* **18**, 2293–2302.
- Lang T & Barling D (2013) Nutrition and sustainability: an emerging food policy discourse. *Proc Nutr Soc* **72**, 1–12.
- Lawrence M, Burlingame B, Caraher M *et al.* (2015) Public health nutrition and sustainability. *Public Health Nutr* **18**, 2287–2292.
- Institute of Medicine (2014) *Sustainable Diets: Food for Healthy People and a Healthy Planet: Workshop Summary*. Washington, DC: The National Academies Press.
- Clonan A & Holdsworth M (2012) The challenge of eating a healthy and sustainable diet. *Am J Clin Nutr* **96**, 459–460.
- Yngve A, Haapala I, Hodge A *et al.* (2012) Public health nutrition and the environment. *Public Health Nutr* **15**, 187–188.
- Johnston JJ, Fanzo JC & Cogill B (2014) Understanding sustainable diets: a descriptive analysis of the determinants and processes that influences diets and their impact on health, food security, and environmental sustainability. *Adv Nutr* **5**, 418–429.
- Meybeck A (2015) Understanding sustainable diets: from diets to food systems, from personal to global. In *Assessing Sustainable Diets Within the Sustainability of Food Systems. Mediterranean Diet, Organic Food: New Challenges. Proceedings of an International Workshop*, pp. 207–214 [A Meybeck, S Redfern, F Paoletti *et al.*, editors]. Rome: FAO.
- Gitz V (2015) Sustainable diets and sustainable food systems. In *Assessing Sustainable Diets Within the Sustainability of Food Systems. Mediterranean Diet, Organic Food: New Challenges. Proceedings of an International Workshop*, pp. 131–136 [A Meybeck, S Redfern, F Paoletti *et al.*, editors]. Rome: FAO.
- High Level Panel of Experts on Food Security and Nutrition (2014) *Food Losses and Waste in the Context of Sustainable Food Systems. A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*. Rome: HLPE.
- Gussow JD & Clancy K (1986) Dietary guidelines for sustainability. *J Nutr Educ* **18**, 1–5.
- Gussow JD (1999) Dietary guidelines for sustainability: twelve years later. *J Nutr Educ* **31**, 194–200.
- US Department of Agriculture (2015) *Scientific Report of the 2015 Dietary Guidelines Advisory Committee*. Washington, DC: USDA.
- Merrigan K, Griffin T, Wilde P *et al.* (2015) Designing a sustainable diet. *Science* **350**, 165–166.
- Seed B (2015) Sustainability in the Qatar national dietary guidelines, among the first to incorporate sustainability principles. *Public Health Nutr* **18**, 2303–2310.
- Ministry of Health of Brazil (2014) *Dietary Guidelines for the Brazilian Population*. Brasilia: Primary Health Care Department, Ministry of Health of Brazil.
- Swedish National Food Agency (2015) *Swedish Dietary Guidelines – Risk and Benefit Management Report*. Uppsala: National Food Agency.
- Health Council of the Netherlands (2011) *Guidelines for a Healthy Diet: The Ecological Perspective*. The Hague: Health Council of the Netherlands.
- German Council for Sustainable Development (2013) *The Sustainable Shopping Basket: A Guide to Better Shopping*. Berlin: German Council for Sustainable Development.
- Burlingame B & Dernini S (editors) (2012) *Sustainable Diets: Directions and Solutions for Policy, Research and Action*. Rome: FAO.
- International Food Policy Research Institute (2015) *Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development*. Washington, DC: IFPRI.
- Alexandratos N & Bruinsma J (2012) *World Agriculture Towards 2030/2050: The 2012 Revision. ESA Working Paper* no. 12–03. Rome: FAO.



23. Smith P & Gregory PJ (2013) Climate change and sustainable food production. *Proc Nutr Soc* **72**, 21–28.
24. Whitmee S, Haines A, Beyrer C *et al.* (2015) Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. *Lancet* **386**, 1973–2028.
25. Tilman D & Clark M (2014) Global diets link environmental sustainability and human health. *Nature* **515**, 518–522.
26. van Dooren C, Marinussen M, Blonk H *et al.* (2014) Exploring dietary guidelines based on ecological and nutritional values: a comparison of six dietary patterns. *Food Policy* **44**, 36–46.
27. Heller MC, Keoleian GA & Willett WC (2013) Toward a life cycle-based, diet-level framework for food environmental impact and nutritional quality assessment: a critical review. *Environ Sci Technol* **47**, 12632–12647.
28. Vanham D, Mekonnen MM & Hoekstra AY (2013) The water footprint of the EU for different diets. *Ecol Indic* **32**, 1–8.
29. Tukker A, Goldbohm RA, de Koning A *et al.* (2011) Environmental impact of changes to healthier diets in Europe. *Ecol Econ* **70**, 1776–1788.
30. Masset G, Vieux F, Verger EO *et al.* (2014) Reducing energy intake and energy density for a sustainable diet: a study based on self-selected diets in French adults. *Am J Clin Nutr* **99**, 1460–1469.
31. Macdiarmid JI (2013) Is a healthy diet an environmentally sustainable diet? *Proc Nutr Soc* **72**, 13–20.
32. Drewnowski A, Rehm CD & Martin A (2015) Energy and nutrient density of foods in relation to their carbon footprint. *Am J Clin Nutr* **101**, 184–191.
33. International Centre for Advanced Mediterranean Agromic Studies/Food and Agriculture Organization of the United Nations (2015) *Mediterranean Food Consumption Patterns: Diet, Environment, Society, Economy and Health. A White Paper Priority 5 of the Expo Milan 2015 Feeding Knowledge Programme*. Rome: FAO.
34. Keys AB (1970) Coronary heart disease in seven countries. *Circulation* **41**, Suppl. 1, 1–200.
35. Gussow JD (1995) Mediterranean diets: are they environmentally responsible? *Am J Clin Nutr* **61**, Suppl. 6, 1383S–1389S.
36. Burlingame B & Dernini S (2011) Sustainable diets: the Mediterranean diet example. *Public Health Nutr* **14**, 2285–2287.
37. Dernini S & Berry EM (2015) Mediterranean diet: from a healthy diet to a sustainable dietary pattern. *Front Nutr* **2**, 15.
38. Katz DL & Meller S (2014) Can we say what diet is best for health? *Annu Rev Public Health* **35**, 83–103.
39. Belahsen R (2014) Cultural diversity of sustainable diets. Nutrition transition and food sustainability. *Proc Nutr Soc* **73**, 385–388.
40. Dernini S, Berry EM, Bach-Faig A *et al.* (2012) A dietary model constructed by scientists: the Mediterranean diet. In *Mediterra 2012: The Mediterranean Diet for Sustainable Regional Development*, pp. 71–88. Paris: CIHEAM–Les Presses de Sciences Po.
41. Bach-Faig A, Berry EM, Lairon D *et al.* (2011) Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutr* **14**, 2274–2284.
42. Food and Agriculture Organization of the United Nations/International Centre for Advanced Mediterranean Agromic Studies (2012) *Towards the Development of Guidelines for Improving the Sustainability of Diets and Food Consumption Patterns in the Mediterranean Area*. Rome: FAO.
43. Dernini S, Meybeck A, Burlingame B *et al.* (2013) Developing a methodological approach for assessing the sustainability of diets: the Mediterranean diet as a case study. *New Medit* **12**, 28–36.
44. Donini LM, Dernini S, Lairon D *et al.* (2016) A consensus proposal for nutritional indicators to assess the sustainability of a healthy diet: the Mediterranean diet as a case study. *Front Nutr* **3**, 37.
45. Trichopoulou A & Lagiou P (1997) Healthy traditional Mediterranean diet: an expression of culture, history and lifestyle. *Nutr Rev* **55**, 383–389.
46. Willett W, Sacks F, Trichopoulou A *et al.* (1995) Mediterranean diet pyramid: a cultural model for healthy eating. *Am J Clin Nutr* **61**, Suppl. 6, 1402S–1406S.
47. de Lorgeril M, Renaud S, Mamelle N *et al.* (1994) Mediterranean α -linolenic acid-rich diet in secondary prevention of coronary heart disease. *Lancet* **343**, 1454–1459.
48. Trichopoulou A, Bamia C & Trichopoulos D (2005) Mediterranean diet and survival among patients with coronary heart disease in Greece. *Arch Intern Med* **165**, 929–935.
49. Estruch R, Ros E, Salas-Salvadó J *et al.* (2013) Primary prevention of cardiovascular disease with a Mediterranean diet. *N Engl J Med* **368**, 1279–1290.
50. Serra-Majem L, Roman B & Estruch R (2006) Scientific evidence of interventions using the Mediterranean diet: a systematic review. *Nutr Rev* **64**, Suppl. 1, S27–S47.
51. Trichopoulou A, Bamia C & Trichopoulos D (2009) Anatomy of health effects of Mediterranean diet: Greek EPIC prospective cohort study. *BMJ* **338**, b2337.
52. Sofi F, Abbate R, Gensini GF *et al.* (2010) Accruing evidence on benefits of adherence to the Mediterranean diet on health: an updated systematic review and meta-analysis. *Am J Clin Nutr* **92**, 1189–1196.
53. Kastorini CM, Milionis HJ, Esposito K *et al.* (2011) The effect of Mediterranean diet on metabolic syndrome and its components: a meta-analysis of 50 studies and 534,906 individuals. *J Am Coll Cardiol* **57**, 1299–1313.
54. Gotsis E, Anagnostis P, Mariolis A *et al.* (2015) Health benefits of the Mediterranean diet: an update of research over the last 5 years. *Angiology* **66**, 304–318.
55. Trichopoulou A, Costacou T & Bamia C (2003) Adherence to a Mediterranean diet and survival in a Greek population. *N Engl J Med* **348**, 2599–2608.
56. La Vecchia C (2009) Association between Mediterranean dietary patterns and cancer risk. *Nutr Rev* **67**, Suppl. 1, S126–S129.
57. Pelucchi C, Bosetti C, Rossi M *et al.* (2009) Selected aspects of Mediterranean diet and cancer risk. *Nutr Cancer* **61**, 756–766.
58. Verbene L, Bach-Faig A, Buckland G *et al.* (2010) Association between the Mediterranean diet and cancer risk: a review of observational studies. *Nutr Cancer* **62**, 860–870.
59. Buckland G, Travier N, Cottet V *et al.* (2013) Adherence to the Mediterranean diet and risk of breast cancer in the European prospective investigation into cancer and nutrition cohort study. *Int J Cancer* **132**, 2918–2927.
60. Giacosa A, Barale R, Bavaresco L *et al.* (2013) Cancer prevention in Europe: the Mediterranean diet as a protective choice. *Eur J Cancer Prev* **22**, 90–95.
61. Serra-Majem L, Bes-Rastrollo M, Roman-Vinas B *et al.* (2009) Dietary patterns and nutritional adequacy in a Mediterranean country. *Br J Nutr* **101**, Suppl. 2, S21–S28.
62. Castro-Quezada I, Román-Viñas B & Serra-Majem L (2014) The Mediterranean diet and nutritional adequacy: a review. *Nutrients* **6**, 231–248.
63. Maillot M, Issa C, Vieux F *et al.* (2011) The shortest way to reach nutritional goals is to adopt Mediterranean food choices. Evidence from computer-generated personalized diets. *Am J Clin Nutr* **94**, 1127–1137.
64. Shai I, Schwarzfuchs D, Henkin Y *et al.* (2008) Weight loss with a low-carbohydrate, Mediterranean or low-fat diet. *N Engl J Med* **359**, 229–241.



65. Buckland G, Bach A & Serra-Majem L (2008) Obesity and the Mediterranean diet: a systematic review of observational and intervention studies. *Obes Rev* **9**, 582–593.
66. Romaguera D, Norat T, Mouw T *et al.* (2009) Adherence to the Mediterranean diet is associated with lower abdominal adiposity in European men and women. *J Nutr* **139**, 1728–1737.
67. Kesse-Guyot E, Fezeu L, Hercberg S *et al.* (2012) Adherence to Mediterranean diet reduces the risk of metabolic syndrome: a 6-year prospective study. *Nutr Metab Cardiovasc Dis* **142**, 909–915.
68. Martínez-González MA, Fuente-Arrillaga C, Nunez-Cordoba JM *et al.* (2008) Adherence to Mediterranean diet and risk of developing diabetes: prospective cohort study. *BMJ* **336**, 1348–1351.
69. Koloverou E, Esposito K, Giugliano D *et al.* (2014) The effect of Mediterranean diet on the development of type 2 diabetes mellitus: a meta-analysis of 10 prospective studies and 136,846 participants. *Metabolism* **63**, 903–911.
70. Trichopoulou A, Kyrozi A, Rossi M *et al.* (2015) Mediterranean diet and cognitive decline over time in an elderly Mediterranean population. *Eur J Nutr* **54**, 1311–1321.
71. Singh B, Parsaik AK, Mielke MM *et al.* (2014) Association of Mediterranean diet with mild cognitive impairment and Alzheimer's disease: a systematic review and meta-analysis. *J Alzheimers Dis* **39**, 271–282.
72. Feart C, Samieri C & Barberger-Gateau P (2015) Mediterranean diet and cognitive health: an update of available knowledge. *Curr Opin Clin Nutr Metab Care* **18**, 51–62.
73. Nosova EV, Conte MS & Grenon SM (2015) Advancing beyond the 'heart-healthy diet' for peripheral arterial disease. *Vasc Surg* **61**, 265–274.
74. Schwingshackl L & Hoffmann G (2014) Mediterranean dietary pattern, inflammation and endothelial function: a systematic review and meta-analysis of intervention trials. *Nutr Metab Cardiovasc Dis* **24**, 929–939.
75. Garcia-Marcos L, Castro-Rodriguez JA, Weinmayr G *et al.* (2013) Influence of Mediterranean diet on asthma in children: a systematic review and meta-analysis. *Pediatr Allergy Immunol* **24**, 330–338.
76. Del Chierico F, Vernocchi P, Dallapiccola B *et al.* (2014) Mediterranean diet and health: food effects on gut microbiota and disease control. *Mol Sci* **15**, 11678–11699.
77. Psaltopoulou T, Sergentanis TN, Panagiotakos DB *et al.* (2013) Mediterranean diet, stroke, cognitive impairment, and depression: a meta-analysis. *Ann Neurol* **74**, 580–591.
78. Sanchez PH, Ruano C, de Irala J *et al.* (2012) Adherence to the Mediterranean diet and quality of life in the SUN project. *Eur J Clin Nutr* **66**, 360–368.
79. Ng M, Fleming T, Robinson M *et al.* (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **384**, 766–781.
80. Abdullah MM, Jones JP & Jones PJ (2015) Economic benefits of the Mediterranean-style diet consumption in Canada and the United States. *Food Nutr Res* **59**, 27541.
81. Sáez Almendros S, Obrador B, Bach-Faigh A *et al.* (2013) Environmental footprints of Mediterranean versus Western dietary patterns: beyond the health benefits of the Mediterranean diet. *Environ Health* **12**, 118.
82. Capone R, Iannetta M, El Bilali H *et al.* (2013) A preliminary assessment of the environmental sustainability of the current Italian dietary pattern: water footprint related food consumption. *J Food Nutr Res* **1**, 59–67.
83. Myers N, Mittermeier RA, Mittermeier CG *et al.* (2000) Biodiversity hotspots for conservation priorities. *Nature* **403**, 853–858.
84. Trichopoulou A, Vasilopoulou E, Georga K *et al.* (2006) Traditional foods: why and how to sustain them. *Trends Food Sci Technol* **17**, 498–504.
85. Trichopoulou A (2012) Diversity *v.* globalization: traditional foods at the epicentre. *Public Health Nutr* **15**, 951–954.
86. Capone R, Lamaddalena N, Lamberti L *et al.* (2012) Food consumption patterns and sustainable natural resources management in the Mediterranean region. *J Food Sci Eng* **2**, 437–451.
87. United Nations Educational, Scientific and Cultural Organization (2010) *Inscription of Mediterranean diet on the Representative List of the Intangible Heritage of Humanity*. Intergovernmental Committee for the Safeguarding of the Intangible Cultural Heritage. Paris: UNESCO.
88. Serra-Majem L & Medina FX (2014) The Mediterranean diet as an intangible and sustainable food culture. In *The Mediterranean Diet: An Evidence-Based Approach*, pp. 37–46 [VR Preedy and DR Watson, editors]. London: Academic Press/Elsevier.
89. Berry EM, Arnoni Y & Aviram M (2011) The Middle Eastern and biblical origins of the Mediterranean diet. *Public Health Nutr* **14**, 2288–2295.
90. Dermeni S & Berry EM (2016) Historical and behavioral perspectives of the Mediterranean Diet. In *Mediterranean Diet in Health and Disease*, pp. 29–41 [DF Romagnolo and OI Selmin, editors]. New York: Humana Press/Springer.
91. Medina FX (2009) Mediterranean diet, culture and heritage: challenges for a new conception. *Public Health Nutr* **12**, 1618–1620.
92. González Turmo I (2012) The Mediterranean diet: consumption, cuisine and food habits. In *Mediterra 2012: The Mediterranean Diet for Sustainable Regional Development*, pp. 115–132. Paris: CIHEAM–Les Presses de Sciences Po.
93. Medina FX (2011) Food consumption and civil society: Mediterranean diet as a sustainable resource for the Mediterranean area. *Public Health Nutr* **14**, 2346–2349.
94. Regmi A, Ballenger N & Putnam J (2004) Globalisation and income growth promote the Mediterranean diet. *Public Health Nutr* **7**, 977–983.
95. Lacirignola C & Capone R (2009) Mediterranean diet: territorial identity and food safety. *New Medit* **4**, 2–3.
96. Capone R, El Bilali H, Debs P *et al.* (2014) Mediterranean food consumption patterns sustainability: setting up a common ground for future research and action. *Am J Nutr Food Sci* **1**, 37–52.
97. Le Mouél C, Forslund A, Marty P *et al.* (2015) *Le système agricole et alimentaire de la région Afrique du Nord – Moyen-Orient à l'horizon 2050: projections de tendance et analyse de sensibilité*. Rapport final d'étude pour Phuriagri. Paris/Rennes: INRA.
98. Capone R, El Bilali H & Bottalico F (2016) Assessing the sustainability of typical agro-food products: insights from Apulia region, Italy. *New Medit* **15**, 28–35.
99. Pekcan G, Köksal E, Küçükerdönmez Ö *et al.* (2006) *Household Food Waste in Turkey*. Statistics Division Working Paper Series no. ESS/ESA/006e. Rome: FAO.
100. Serra-Majem L, Trichopoulou A, de la Cruz JN *et al.* (2004) Does the definition of the Mediterranean diet need to be updated? *Public Health Nutr* **7**, 927–929.
101. Davis C, Bryan J, Hodgson J *et al.* (2015) Definition of the Mediterranean diet: a literature review. *Nutrients* **7**, 9139–9153.
102. Pisco S (2009) The Mediterranean diet as a nutrition education, health promotion and disease prevention tool. *Public Health Nutr* **12**, 1648–1655.
103. Serra-Majem L & Trichopoulou A (2016) Updating the benefits of the Mediterranean diet: from the hearth to the earth. In *Mediterranean Diet in Health and Disease*, pp. 3–14 [DF Romagnolo and OI Selmin, editors]. New York: Humana Press/Springer.