

REVIEW

Foods of the Mediterranean diet: lacto-fermented food, the food pyramid and food combinations

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Summary

The Mediterranean diet proved to be one of the healthiest diets in the world. It has several beneficial effects and it prevents many non-communicable diseases, such as cancer, cardiovascular diseases, and obesity. Before being a culinary regime, the Mediterranean diet is characterized by specific cultural heritages and traditions, also influencing the lifestyle of the populations. The Mediterranean diet follows the so-called food pyramid, comprising several food combinations. Indeed, it is mainly composed by vegetables, fish and dairy products, while red meat and sweets are poorly consumed. Processed foods are mainly avoided, apart from lacto-fermented ones, the first processed foods consumed by humans. Food fermentation by microorganisms not only improves the func-

tionality of bioactive metabolites, but also increases the shelf life and organoleptic properties of the food. Lactic acid bacteria play a vital role in transforming the food constituents, thereby enhancing their nutritional and functional properties. In addition, these foods introduce beneficial bacteria into gut microbiota, thus maintaining a healthy gut microbiome and corresponding gut-brain axis, thus providing an overall improvement in health and a reduced risk of non-communicable diseases and metabolic disorders.

This review will focus on the Mediterranean diet, on its characterising food pyramid and food combinations, and on lacto-fermented foods, one of the components of the Mediterranean diet with the most beneficial effects.

Introduction

The Mediterranean diet was awarded Intangible Cultural Heritage of Humanity status by UNESCO in 2010 [1, 2]: it is not only a diet, but also a tradition and symbolism of the Mediterranean region, its cuisines, and its people, and also a healthy way of living [1]. Mediterranean people have traditionally based their cuisine on the interactively woven ideas, habits, and values of the Mediterranean community, as well as the individual groups and subgroups of each Mediterranean country. The Mediterranean cuisine is a blend of their traditions and tastes, and it symbolizes the richness of the Mediterranean heritage [2].

The Mediterranean cuisine is mainly comprised of cereals, fruits, and vegetables (which can be consumed raw, cooked, or pickled), white meat, plenty of olive oil, fermented foods, and dairy products. Fermented foods have been conventionally used in the Mediterranean countries since ancient times, owing to their organoleptic properties and long shelf-life. Currently, lacto-fermented foods (that is, foods that have been fermented by lactic acid bacteria or LAB, usually belonging to genera such as *Lactobacillus*, *Leuconostoc*, and *Streptococcus*) have gained much focus because of their health-promoting properties [3]. These types of foods are naturally rich in lactic acid bacteria, which depend upon a fermentable

sugar for their metabolism and growth [4]. The product of fermentation is either lactic acid alone (homo-fermentation) or a combination of acetic acid, lactic acid, carbon dioxide and ethanol (heterofermentation) [5]. The lactic acid fermentation of sugars in raw foods not only coins a peculiar flavour and texture to the food, but also releases an array of signalling molecules and health-promoting compounds that interact with the gut microbiota [6], thus bringing many health benefits to it. Thanks to the properties of the lactic acid bacteria and their metabolites, many of these foods are classified as “functional foods” [7]: owing to their myriad of positive effects on human health, these foods are considered as reliable and inexpensive means of improving human health.

LAB-fermented foods and their health benefiting effects

FERMENTED PROBIOTICS AND DAIRY PRODUCTS

Milk is a good source of lacto-fermented foods, such as yogurt and cheese. The lactose in milk is fermented to lactic acid by the LAB *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* [8]; this process decreases the milk pH, thus preventing the development of pathogenic microbes. In addition, lactic acid fermentation generates many useful metabolites – such as

essential amino acids, bioactive compounds, vitamins, minerals, and exopolysaccharides – that enhance the nutritive value of the product [9].

Today, a wide variety of fermented dairy products is available, ranging from plain yogurt to flavoured yogurt and finely textured Greek yogurt, which contain absorbable forms of vitamins and minerals [10]; branched-chain amino acids (BCAA), which enhance muscle growth and maintain the body bioactive peptides, with health promoting effects [8, 9]; unsaturated fatty acids, which help to absorb fat-soluble vitamins A, D, E, and K, and conjugated linoleic acid. The conjugated linoleic acid exhibits anti-cancerous properties, by inducing apoptosis specifically in breast cancer cells [11, 12]. The bacteria in yogurt contribute to the transient microbiota and thus improve the gut environment. Several studies have also suggested beneficial effects of yogurt in managing type 2 diabetes. For instance, a study based on meta-analysis of randomised controlled trials regarding use of yogurt for managing type 2 diabetes mentioned that its regular consumption results in a reduction in complications [13]. This might be due to the alteration and modulation of gut microbiota, which prevent dysbiosis and improve the overall digestion. In addition, the gut microbiome plays an important role in improving liver and cognitive functions by participating in the gut-brain axis [14]. For instance, the consumption of yogurt along with fruits helps in improving the non-alcoholic fatty liver disease (NAFL) [15]. Similarly, yogurt supplementation decreases the deposition of the myeloid-beta plaques in the brain cortex and hippocampus in the early stages of life [16, 17]. This indicates that yogurt is beneficial for improving gut microbiota and the corresponding gut-brain axis, which modulates the overall health of an individual and prevents non-communicable diseases and metabolic disorder [16-18].

KEFIR

Kefir is a natural complex probiotic, derived from kefir grains by the combined action of LAB, Acetic Acid Bacteria (AAB), and yeasts, enveloped in a slimy matrix composed of EPS and proteins [19]. Traditionally, Kefir has been used as a health-promoting and life-prolonging fermented milk [20], as it is said to possess anticancer, antidiabetic, antidepressive, anti-allergic, antiasthma, and immunomodulatory effects [21, 22]. Kefir plays an important role in improving the gut microbiota by suppressing the bacteroides and increasing LAB and Bifidobacterial species, thereby improving hypertension, inflammation, and fasting sugar levels in patients suffering from metabolic disorders [23, 24]. In addition, it has been implicated in managing NAFL and high-fat diet induced obesity. A study on mouse model reported that 0.2 mL supplementation of Kefir decreased the incidence of obesity by 60% in test mice, as compared to controls, by reducing systemic inflammation and blood cholesterol levels. This could be due to the fact that kefir LAB colonize the gut epithelium, thereby exerting an influence on overall gut microbiota by niche exclusion and lactic acid production, which reduces the pH by creating an acid-

ic environment that suppress the growth of bacteroides and induces the expression of genes encoding beneficial digestive enzymes [24]. In addition, the probiotics in kefir upregulate the expression of peroxisome proliferator-activate receptor, thereby playing a vital role in beta oxidation of fatty acids in the liver and thus in the NAFL disease management [25]. Moreover, kefir bioactive metabolites, EPS, and sphingolipids exhibit anticancer properties, possibly by mediating the signalling pathways involved in proliferation and apoptosis of cancer cells [26]. Kefir has also been indicated in improving sleep quality and reducing the incidence of mental disorders in postmenopausal women. Furthermore, it helps in bowel movements, modulates immunity, improves both physical and mental health (reducing anxiety, depression, and stress) and, thus, the individual's overall quality of life [27]. In addition, kefir releases short-chain fatty acids (SCFAs) in the gut, which improves bone density and bone formation, which also prevents fractures in the elderly [28]. This repertoire of health benefits, of course, can be retrieved when used in moderate amounts. In fact, the Mediterranean diet regime includes kefir consumption in moderate quantities, along with other dairy products like Greek yogurt and feta cheese.

CHEESE

Another popular fermented dairy product of the Mediterranean region is cheese (such as pecorino, halloumi, brie, chevre, manchego, feta, Parmigiano Reggiano, ricotta...), whose consumption in low to moderate amounts is recommended in this diet [29]. Cheese is good for lactose intolerant people, as the LAB completely consume this sugar during the prolonged ripening of the cheese. During the initial fermentation stages, the LAB use milk carbohydrates, leaving behind indigestible oligosaccharides, whose consumption exerts prebiotic effects and enhances the beneficial gut microbiota [30]. Not only cheese is an excellent source of prebiotics, but it also has strong anti-inflammatory properties. For instance, in a recent study it was observed that cheese produced using *L. delbrueckii* subsp. *lactis* CNRZ327 and *P. freudenreichii* ITG protected against epithelial cell damage and colitis in mice, as compared to controls [31]. In addition, studies have reported the cholesterol-lowering effects of cheddar and Turkish cheese [32]. Similarly, *Lactobacillus*- and *Lactococcus*-fermented cheese products contain bioactive peptides that have satiety regulation, antimicrobial, antithrombotic, anticarcinogenic, hypotensive, stress-relieving, mineral absorptive and anti-inflammatory properties [33].

VEGETABLE FERMENTED PRODUCTS

The long history of traditional pickles and fermented vegetables indicates both their culinary and health-promoting potential. A recent shift to use of fermented food has brought attention to traditionally fermented vegetables that were being used throughout the world since ancient times, such as kimchi (fermented vegetables with spices and seafood), sauerkrauts (fermented cabbage), gundruk (fermented leaf), and various kinds of pickles.

Fermentation and pickling not only enhance the bioactivity of these vegetables, but also increase their shelf life [34].

Sauerkrauts

Sauerkrauts are produced by spontaneous or selective fermentation of cabbage by specific bacteria: for instance, *Lactobacillus sakei*-fermented vegetables and sauerkrauts show three times more bioactivity as compared to those fermented by any other strain [35]. Fermentation enhances the cabbage's amount of vitamin C, fibre, ethanol, organic acids (e.g. lactic acid, maleic acid, acetic acid, and succinic acid), short chain fatty acids (e.g. propionic acid), and acetaldehyde. It also enhances the bioactivity of its glucosinolates, which are normally not bioavailable in the fresh product. Sauerkraut exerts many beneficial effects on health, such as improvement of gut microbiota in patients suffering from IBS, as indicated by the changes in fecal microbial composition [36]. Sauerkrauts show antitumor activity by inducing apoptosis of cancer cells, exerting inflammation-modulating effects, and inhibiting tumour invasion in different tissues [35]. Besides that, owing to its vitamins and organic acids, it has a strong antioxidant potential [37]. It also exhibits antidepressive effects by inhibiting Mono Ammino Oxidase (MAOs), thus helping in anxiety, depression, and even in the onset of Parkinson's disease [38].

Fermented table olives

Table olive are the most common traditional fermented vegetables in the Mediterranean region, with an increasing demand worldwide and with Italy, Spain, Egypt, Turkey, Greece, Algeria, and Portugal as the main producers. Their production exceeded 2.9 million tons in 2017-2018, which was still less than the overall demand [39]. The fermentation of oleuropein not only brings added value to the end product in terms of bioactive compounds, dietary fibres, fatty acids, and antioxidants, but, owing to the bitter taste it gives to the olives, it increases their culinary value as well [40]. The process of olive fermentation is quite complex, as it involves a wide array of microorganisms and LAB (e.g. *Lactobacillus plantarum* or *Lactobacillus pentosus*) and yeasts (e.g. *Saccharomyces cerevisiae*, *Wickerhamomyces anomalous*, *Candida boidinii*, etc.) [41, 42]. The fermentation of olives by these microbes adds flavor, improves texture, and ensures consumer safety [40].

The probiotic trait of olives makes them an excellent source of gut friendly bacteria that stick to the fruit and are ingested along with it. The probiotics contained in fermented olives bring several health benefits, such as protection against different kinds of cancer, bowel irregularities, intestinal infections, allergic reactions, constipation, and indigestion [43]; apart from having immunomodulatory, antioxidant, and antiatherogenic properties. Fermented olives are also rich in oleic acid, which has a protective effect against breast, prostate, and colon cancer [44, 45]. Moreover, table olives contain hydroxytyrosol, a polyphenol with anti-inflammatory and anti-mi-

crobial activities, proposed for the treatments of several diseases, among which lymphedema and viral infections [46-53]. Table olives also contain high levels of oleocanthal, a natural COX-inhibitor that also protects against certain cancers and neurodegenerative disorders [54]. Furthermore, fermentation of olives inhibits the growth of many pathogenic and spoilage microorganisms [55]. This implicates that fermented olives are a potential source of undiscovered healthy microbial strains and bioactive compounds, which might be the secret behind the health promoting effects of Mediterranean diet.

FERMENTED MEAT AND MEAT PRODUCTS

Meat fermentation is the most ancient and commonly used form of fermentation. Traditional fermented meat products are valuable and popular for a variety of reasons, and are used in many popular cuisines. Fermented meat products are one of the most economically important commodities in Europe, specifically in the Mediterranean countries, where they are representative of a rich cultural heritage [56]. Meat fermentation comprises many biochemical, microbiological, and chemical changes, which bring added value to fermented meat products in terms of taste, colour, aroma, and odour. Lactic acid bacteria play a core role in the fermentation of meat by reducing its pH levels and facilitating the production of bacteriocins, which prevent the growth of pathogenic and spoilage microorganisms and ultimately improve the safety, stability, and shelf life of these products [57]. Preserved fish and fermented meat sausages has also been an important tradition of the Mediterranean culture [58]. Preserved fish was the main ingredient of *garum*, an extremely popular fish sauce in ancient times that was used as a condiment in the ancient Greek, Roman, and Byzantine cuisines [59], which closely resembles the fermented anchovy sauce called *colatura di alici* that is still produced in Campania, Italy. Dry fermented sausages are also an important fermented meat product of the Mediterranean region [60]. Table I reports a list of lacto-fermented foods and of the microorganisms involved in their fermentation.

The Mediterranean food pyramid

The Mediterranean food pyramid is representative of the Med Diet and was developed based on the eating habits of long-living adults in the Mediterranean Region [68]. The pyramid follows general guidelines on choice of food items and not their quantities. Nutritional experts, sociologists, anthropologists, and agriculturists have collectively contributed to the development of what we currently call the Mediterranean diet by adapting the pyramid to the new way of life of the Mediterranean region [69]. The new pyramid follows the pattern of the old one, with plant-based staple foods that should be consumed in larger quantities (such as cereals, fruits, and vegetables) at its base, the ones to be consumed in moderate amounts in the upper levels, and the ones to be consumed in low amounts at the top.

Tab. I. Lacto-fermented foods and the microorganisms that induce their fermentation.

| Source | Microorganism(s) | Fermented Food Product | References |
|--------------------|--|---|------------|
| Milk | <i>S. thermophilus</i> , <i>L. delbrueckii ssp. bulgaricus</i> | Cheese, Yogurt | [61] |
| Meat | <i>Lactobacillus sake</i> , <i>L. plantarum</i> | Sausages (e.g. Salami) | [62] |
| Grains | <i>Sacchromyces cerevisiae</i> , <i>L. brevis</i> | Yeast bread, beer, sake, Chinese rice wine and rice vinegar | [63] |
| Plants | <i>L. plantarum</i> , <i>L. brevis</i> | Kimchi, sauerkraut, olives, Szechuan pickled vegetables | [64] |
| Legumes | <i>A. soyae</i> , <i>Z. rouxii</i> , <i>T. halophilus</i> | Fermented bean curd, bean paste, miso, soya sauce | [65] |
| Fruits | <i>S. cerevisiae</i> | Wine, vinegar | [66] |
| Fish and shellfish | <i>Lactobacillus brevis</i> | Fermented fish, fish sauce, shrimp paste | [67] |

The Med Diet, however, is not just the choice of certain foods rather than others, but is also the way the inhabitants of this region select, prepare, and enjoy said food together. The new Med Diet food pyramid includes ingredients from all the food groups in appropriate proportions and frequencies, and is addressed generally to the healthy adult population; however, it is flexible enough also to cater pregnant women, children, and people with different pathophysiological conditions [70]. Putting together foods from various levels of this food pyramid makes a balanced healthy diet and promotes a healthy lifestyle. The guidelines established by the pyramid for daily, weekly, and occasional foods are represented in Table II [69, 70].

The Mediterranean food combinations

Perhaps the most important thing in adapting to this culinary regime is to understand its cultural heritage and the traditions behind various food combinations. It is not simply a diet, but a lifestyle: not only it involves healthy eating, but also certain ways of cooking, seasonality of products, and socialization and community interactions [71]. Accordingly, to retrieve all the health-promoting benefits of this dietary regime, one must understand the Mediterranean food combinations.

Addressing the issue of food consumption in the Mediterranean region means perceiving it as a practice that is so well-knitted to the rest of the activities making up the

Tab. II. The Med Diet food pyramid: food choices, servings, and frequencies.

| Foods | Quantities/serving | Frequency | Benefits |
|--|--|------------|--|
| Wholegrain cereals | One or two servings per meal in the form of bread, pasta, couscous, rice, millet, etc. | Daily | Source of iron, magnesium phosphorous, micronutrients |
| Vegetables | Two servings per meal at lunch and dinner (at least one serving should be raw) | Daily | Source of antioxidant, anticancer, and antidiabetic compounds |
| Fruits | One or two servings per meal | Daily | Satisfy sweet cravings and source of antioxidants |
| Dairy products | One or two servings of low-fat yogurt, Greek yogurt, and different types of cheese | Daily | Source of saturated fats and calcium maintenance of bones |
| Olive oil | One tablespoon per person for salad dressing, moderate consumption in cooking | Daily | Has a central position in the pyramid as a principal source of dietary lipids, maintains the blood lipid profile, has cardioprotective properties, lowers the risk of developing atherosclerosis |
| Spices, herbs, garlic, onions, olives, nuts, and seeds | Handful of olives, nuts, and seeds as snacks. Garlic and onion in salads, cooking main course dishes, soups, etc. | Daily | Improve flavour and palatability of the food and are rich in healthy lipids, proteins, vitamins, minerals, and fibre |
| Fermented beverages | One glass per day (women) or two glasses per day (men), recommended during meals | Daily | Source of probiotics and maintain gut microbiota |
| Animal (fish, red meat, eggs) and plant proteins | Both animal and plant proteins can be consumed, with animal proteins only for taste (fish: two or more servings, red meat: two servings, eggs: two to four servings) | Weekly | Source of healthy amino acids and fats |
| Sugary and unhealthy fat rich foods | Very low amounts | Occasional | Med Diet regime supports a very low and occasional consumptions of sweets and confectionaries, to avoid negative health effects |

food event that it cannot be considered alone. For instance, consumption of the Mediterranean diet cannot be separated from its production, cultural traditions, social practices, and methods that have evolved with history and are built around food and nutrition [72]. For this very reason the Med Diet is not just a dietary regime, but a concept that encompasses cultural heritages, values and traditions, biodiversity sustainability, and, ultimately, health and wellbeing.

THE CULINARY DISTINCTIONS OF THE MEDITERRANEAN DIET

Mediterranean cuisine includes foods from the Mediterranean basin, which includes countries like Syria, Turkey, Egypt, Spain, Italy, and Greece. This region is famous for its rich history, which results in a wide diversity in cultures, social structures, ethnic groups, occupations, and religions [73]. This cultural diversity is strongly reflected in the combinations of condiments and procedures, collectively constituting a culinary system that encompasses a common historical and regional framework. The distinguishing criterion for the Mediterranean cuisine within the different countries is the choice of the staple food that is eaten by all socioeconomic classes. The second distinguishing feature is the cereal or groups of cereals, along with the accompanying elements, condiments, and methods [72].

The third element of distinction is the significant regional and cultural difference among various countries of the Mediterranean, which enables us to divide the Mediterranean into three culinary regions: Southern Europe, Eastern Mediterranean, and North Africa [74].

Southern European cuisine

Southern European cuisine is typical of Southern France, Italy, and Spain, and is characterised by specific distinctive ingredients. Unlike other Mediterranean cuisines, wine is an important element of this cuisine. In addition, the main source of meat is pork, preferred over lamb/mutton or goat. The staple foods are pastas, leavened breads, and rice; and a wide variety of grains are used. Food flavoring is done by using garlic, mustard, anise, tomatoes, capers, anchovies, and pine nuts [75].

Eastern Mediterranean cuisine

This culinary region comprises Middle Eastern cuisine and the culinary traditions of Turkey, Greece, Egypt, Syria, Lebanon, Palestine, Israel. The prominent foods of this region include yogurt, which is widely consumed and also used in sauces and condiments, and fresh cheeses like halloumi and feta, that can be either cooked or consumed raw in a wide variety of culinary assortments. The flavouring is carried out by mint, parsley, sumac, and lemon juice, with pomegranates and nuts as common ingredient in spreads and sauces. Cereals and grains are consumed, also in the form of pitas and lavash. Bulgur wheat is also added to salads, like tabbouleh. The main sources of animal proteins are mutton, lamb, goat and poultry, for example in the form of grilled kebabs, kibbeh, and stir-fried gyros. Chickpeas are used as a meat substitute and are either cooked whole, fried, or in the form of a paste, known as hummus [76].

North African cuisine

This cuisine is distinguished from others by its plentiful use of spices: cumin, saffron, coriander, cinnamon, chillies, cloves, and paprika are regularly used in the cooking traditions of Morocco, Algeria, Tunisia, and Libya. Harissa and ras el hanout are two intense spice mixtures, mostly used in Moroccan cuisine, that give heat to stews and sauces. Preserved dried lemons are used to add a peculiar, brined taste to the North African cuisine. Commonly used grains and cereals are couscous and granular semolina, often consumed with lamb, mutton, and goat meat-based dishes and stews [77]. Chicken and beef are also regularly used in this cuisine. Dried fruits like apricots, dates, and raisins are frequently used, both raw and in cooked dishes. One of the most famous dishes of this region is the Moroccan tagine, a blend of slow-cooked stew of vegetables, meat, and sauce, named after the cone-shaped earthenware pot in which it is cooked [78]. Hibiscus tea and juices containing hibiscus extract are popular drinks of this region [79].

Conclusions

The Mediterranean cuisine is a blend of the values, practices, and exchange of ideas in the Mediterranean basin, which shaped and developed the culinary habits and appetites of the diverse Mediterranean cultures. It is a complex and interactive food system: not just a mere selection of foods, but a network of cultural practices that has come up with a healthy dietary regime. This wonderful cultural heritage needs to be preserved not only for the culinary satisfaction of the people of the world, but also for providing mankind with a diet that sustains health and wellbeing.

The Mediterranean diet, being the healthiest diet regime of the world, is a repertoire of healthy food choices that, when consumed in the recommended manner and followed in a holistic way, as do the Mediterranean people, can sustain a healthy and long life. An important role among the beneficial functional foods of this dietary regime are the fermented foods, which not only improve the gut microbiota, but also create an improved immune system, better bowel movements, reduce harmful gut bacteria, and maintain the gut-brain axis, which is the key to human health. In addition to the aforementioned health benefits, fermented foods have antioxidant and anti-cancerous properties, making them ideal as low-cost nutraceuticals. Adapting to this diet regime and adhering to its recommendations can support a healthy lifestyle, both in healthy individuals and in people suffering from underlying pathophysiological conditions.

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Conflicts of interest statement

Authors declare no conflict of interest.

Author's contributions

MB: study conception, editing and critical revision of the manuscript; ZN, GB, MCM, BA, VV, GM, AI: literature search, editing and critical revision of the manuscript. All authors have read and approved the final manuscript.

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