Review

Foods of the Mediterranean diet: garlic and Mediterranean legumes

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Summary

The Mediterranean diet is a dietary regime derived from the one followed by the ancient civilizations of the Mediterranean region. It is characterized by many healthy constituents, among which are cereals, legumes, fruits, vegetables, olives, and white meat. Many studies suggest that this dietary regime is the key to obtaining a healthy and long life, like that of the Mediterranean peoples. Despite its popularity among health professionals, this diet is still confined to a certain geographical area of the world. Due to globalization and the modern busy lifestyle, this cultural diet is losing ground even in its home region, with more and more people embracing the so-called Western diet. An awareness of health benefits of the individual components of the Mediterranean diet will therefore draw attention from all over the world to this healthy and affordable dietary pattern, which can not only improve the overall health, but also reduce the risk of developing chronic and infectious diseases. In this regard, garlic and Mediterranean legumes present a huge repertoire of phytochemicals having both nutritive and nutraceutical properties, which therefore should be included in our daily dietary routines in moderate proportions. This narrative review aims at summarizing the principal components and health benefits of the Mediterranean diet, in particular of garlic and legumes.

Introduction

Food is one of the most important attractions of our lives. The choice, quality, and quantity of food determines and defines our mental and physical health. Research has shown that the individual taste perception, encoded by taste genes, becomes a guiding force in the selection of food to satisfy our dietary demands. In addition, variations in the taste genes result in different taste perceptions, resulting in varied food choices and to the associated diet-related metabolic syndromes and diseases, such as cardiovascular problems, cancer diabetes, and obesity [1]. On the other hand, the chemical compounds from food activate various taste receptors, altered by genetic polymorphism in taste genes, indicating a complex relation between taste perception and preferences influenced by genetic and environmental factors [2]. This partially justifies why different geographical areas of the world have different food traditions and their corresponding lifestyles and diseases. People living in different parts of the world have developed dietary habits overtime that have influenced the expression of taste genes and coined taste perception and food preferences. For instance, the Mediterranean region is known for the healthy dietary pattern of its populations and the corresponding healthy lifestyle, with a significantly lowered risk of metabolic disorders and associated diseases. The term Mediterranean diet (Med Diet) therefore represents the healthy food choices of the Mediterranean peoples that gained considerable fame a few decades ago, when numerous large-scale clinical studies reported enhanced cardiac protection by reduced atherosclerosis in the populations used to this dietary regime [3]. Subsequent trials supported the notion that the Med Diet indeed proved beneficial also in lowering the risk of other pathophysiological conditions, including metabolic syndromes, neurodegenerative diseases, ocular diseases, type 2 diabetes mellitus, obesity, and cancer [4]. Currently, the Med Diet is considered among the healthiest dietary regimes of the world and it is equally favoured by medical practitioners and nutritionist; however, the implementation of this diet on a global scale to provide health benefits in geographically diverse populations is challenged by numerous socio-economic and cultural factors [5]. In addition to the daily consumption of fruits, vegetables, cereals, and legumes, this diet is also characterized by the inclusion of healthy spices: not only they add flavour and aroma to the foods, but also provide healthy nutrients and phytochemicals. These spices include but are not limited to basil, bay leaf, fennel, cloves, cumin, ginger, turmeric, garlic, oregano, rosemary, mint, parsley, thyme, and sage, and are used in different combinations and proportion in the different areas of the Mediterranean region. These spices not only enhance the culinary essence of the food, but they also make it nutrient-dense because of their antioxidant, anti-cancer, antimicrobial, and anti-inflammatory contents, thus playing a major role in promoting a healthy lifestyle [6]. In this review we will discuss about two important components of the

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Med Diet, i.e. garlic and legumes: not only they confer taste, but they also provide several health benefits to this dietary regime.

Garlic

Garlic (*Allium sativum*) is an essential ingredient of almost all Mediterranean dishes. Being rich in bioactive compounds – such as phenolic compounds, saponins, organic sulphides, and polysaccharides – garlic is not only a food, but it is also part of the traditional medicine in the Mediterranean region, India, and China [7].
Having a repertoire of beneficial bioactive compounds (like polyphenols and flavonoids) conferring it anti-inflammatory, immunomodulatory, cardioprotective, anticancer, antidiabetic, anti-obesity, antihypertensive, antibiotic, and antioxidant properties, garlic is considered as one of the most important vegetables and spices in the world (Tab. I) [8]. Consequently, garlic consumption has been reported to decrease non-communicable diseases such as hypertension, cardiovascular problems, cancer, obesity, and diabetes [9,10].
In addition to the bioactive compounds mentioned above, garlic contains 28% (w/w) carbohydrates (such as starch, sucrose, glucose, and fructose) and fatty acids (such as palmitic acid, linoleic acid, oleic acid, and linolenic acid) [17-20]. Since ancient times, garlic has been used as an anti-microbial and anti-inflammatory agent. In addition, it reduces the risk of chronic cardiovascular problems, suppresses and cures cancer, promotes immunological function, lowers cholesterol, detoxifies harmful compounds, restores physical strength, enhances resistance against stress and pathogens, and mediates antiaging, anti-cancer, hepatoprotective and renoprotective effects [14]. Garlic can be consumed raw, dried, or cooked, as a whole or in an extract form. Its consumption as an extract has been observed to reduce the risk of initiation, development, and proliferation of several types of cancers, such as breast, skin, uterine, colon, cervix, and gastric cancer [21, 22]. The presence of organosulfur compounds in garlic makes it a potent inhibitor of cancer cell proliferation and an inducer of apoptosis

Tab. I. Some important phytochemicals and bioactive constituents of garlic.

Types	Percent (g/ 100 gW)	Bioactive Compounds	Bioactivities	Therapeutic effects	References
Sulphur-containing compounds	2.3%	Thiosulphinates like allicin, allylmethyl-, methylallyl- and trans-1-propenyl-thiosulfinate	Allicin inhibits the growth of *Staphylococcus aureus*, *Salmonella typhimurium*, *Escherichia coli*, *Bacillus cereus*, *Helicobacter pylori*, and *Streptococcus thermophilus*	Antimicrobial, urease inhibition	[11, 12]
		OrganoSulphur volatiles, including Diallyl disulfides (DADS), Diallyl sulfides (DAS), Diallyly trisulfides (DATS), sulfur dioxide, E/Z-ajoene, S-allyl-cysteine (SAC), and S-allyl-cysteine sulfoxide (alliin), S-allyl mercapto cysteine (SAMC)	SAC AND SAMC have strong radical scavenging activities, DAS and DADS enhance the activity of glutathione reductase	Antioxidants, prevent damage caused by free radicals, anti-cancer	[13, 14]
		Vinyldithiins including 2-vinyl-4H-1,3 dithiin	Lowers platelet aggregation	Antioxidants, cardioprotective, prevent myocardial infarction and ischemic stroke, reduce the risk of gastric and colon cancer	[15,16]
Phenols	1.5%	β-resorcylic acid, pyrogallol, protocatechuic acid, gallic acid, rutin, and quercetin	Scavenge free radicals, relax coronary arteries, prevent myocardial	Antioxidants, cardioprotective effects	[17, 18]
Non-sulphur containing saponins		β-cholorogenin, diosgenin, desgalactotigonin-rhamnose, proto-desgalactotigonin-rhamnose, voghieroside D1, sativoside B1-rhamnose, and sativoside R1 gitogenin and proto-desgalactotigonin	Inhibit fungal pathogens, protect against reactive oxygen species, prevent DNA damage	Antifungal, antitumor, antithrombotic, and cholesterol-lowering effects	[14, 19]
Amino acids	1.2 %	Arginine, leucine, glutamic acid, and aspartic acid	Arginine is a precursor of neurotransmitter nitric oxide, they smooth muscle relaxation and lower blood pressure	Neurotransmission, antihypertensive	[20]

in many types of cancers [14, 22, 23]. Although studies proving the therapeutic potentials of garlic are based on in vitro and in vivo animal models, some small-scale clinician trials in humans have provided an insight into the nutraceutical potential of garlic in both raw and commercial forms (Tab. II).

Legumes

Legumes such as alfalfa, green beans, clover, peanuts, lupines, peas, soybeans, broad beans, dry beans, chickpeas, dry peas, and lentils are important source of vegetable-based proteins and are important ingredients of many world-famous diet plans. Peas, beans, chickpeas and lentils are considered cornerstones of many ancient diet patterns, including the Mediterranean diet. These legumes are not only low in fat with no cholesterol, but are also heavily loaded with proteins, starch, minerals, vitamin, and fibre, making them as important as cereals in our daily diet. In the Med Diet legumes are taken daily in moderate proportions in cooked, baked, and raw form, as sprouts or salads. Being more proteinaceous than cereals, these legumes can be used as a primary source of

Tab. II. The biological activities of garlic and its active components as shown by clinical trials.

Bioactivities	Subjects/ patients	Study design	Interventions and duration	Results	References
Antioxidant properties	92 obese patients	Placebo-controlled randomized double-blind trial	400 mg of garlic extract per day for 3 months	Enhanced production of antioxidant	[24]
	46 untrained boys	Randomized controlled trial	250 mg garlic capsule per day for 8 weeks	Lowered oxidative stress and enhanced resistance and endurance during training	[25]
	44 pregnant women	Placebo-controlled randomized double-blind trial	1 mg of allicin plus 400 mg garlic per day for 9 weeks	Reduced oxidative stress	[26]
	42 menopausal women	Randomized double-blind controlled trial	1200 µg allicin per day for one year	Reduced oxidative stress	[27]
Anti-inflammatory properties	120 healthy individuals	Placebo-controlled randomized double-blind parallel intervention study	2.56 g aged garlic extract (AGE) per day for 90 days	Enhanced immune system functions	[28]
	120 healthy subjects	Randomized double-blind placebo-controlled nutrition intervention	2.56 g aged garlic extract per day for 90 days	Improved immune system function, less cold and flu symptoms	[29]
	60 healthy volunteers	Randomized controlled trial	1 g to 3 g of garlic powder 6.0 and 24.0 h respectively	Immunostimulatory effect	[30]
	51 healthy but obese adults	Placebo-controlled double-blind randomized trial	3.6 g aged garlic extract per day for 6 weeks	Reduced inflammation	[31]
Lipid lowering effects	160 type 2 diabetic patients	Randomized control trial	500 mg of garlic powder and 1.1 mL of olive oil for 3 months	Prevented dyslipidaemia	[32]
	150 hyperlipidaemic patients	Single-blind placebo-controlled study	1 mg allicin and 400 mg garlic in tablet, twice daily for 6 weeks	Lowered lipid levels	[33]
	75 healthy adults	Placebo-controlled randomized double-blind trial	10.8 mg allicin (3 garlic cloves) per day for 12 weeks	Lipid-lowering effects	[34]
	70 diabetic patients with dyslipidaemia	Placebo controlled randomized single-blind study	Garlic tablet 300 mg, 2 times daily for 12 weeks	Improvements in dyslipidaemia	[35]
Antidiabetic effects	210 type 2 diabetes mellitus patients	Placebo-controlled single-blind study	Garlic tablet 300 - 1500 mg per day plus Metformin 500 mg twice a day for 24 weeks	Reduced HbA_{1c} and fasting blood glucose levels	[36]

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Tab. II. *Continues.*

Bioactivities	Subjects/ patients	Study design	Interventions and duration	Results	References
Antidiabetic effects	Two 38-subject groups having diabetes	Double blind trial	750 mg capsule containing onion and garlic 20% (w/w), nettle leaf 20% (w/w), berry leaf 10% (w/w), walnut leaf 20% (w/w), fenugreek seed 20% (w/w), and cinnamon bark 10% (w/w), thrice daily for 12 weeks	Decreased HbA_{1c} and fasting blood sugar level.	[37]
Bone diseases	80 overweight or obese postmenopausal women with knee osteoarthritis (OA)	Placebo-controlled parallel-design randomized double-blind trial	500 mg garlic tablet twice daily for 12 weeks	Improved OA symptoms	[38]
	76 overweight or obese postmenopausal women	Placebo-controlled randomized double-blind parallel design trial	1000 mg garlic tablet per day for 12 weeks	Reduced pain severity	[39]
	44 postmenopausal osteoporotic women	Double-blind randomized controlled clinical trial	2 garlic tablets per day for 8 months	Immunomodulatory effects	[27]
Antimicrobial effects	45 children	Randomized double-blind controlled clinical trial	2 mL garlic or garlic with lime formulation, used as mouth rinse, once a day for 2 weeks	Economic and effective alternative to sodium fluoride mouth rinse	[40]
Antiviral effects on respiratory viral infections	796 children	Double-blind placebo-controlled randomized trial	First stage Allicor 600 mg and second stage Allicor 300 mg tablets per day for 5 months	Effective in the prevention of nonspecific acute respiratory infections, without any side effects	[41]
Anticancer effects	57,560 men and women	Comparison-based study	One bulb of garlic per day for 9 years	Reduced risk of colorectal adenoma	[42]
	1,424 lung cancer cases and 4,543 healthy controls	Population-based case control study	Weekly administration of 8.4 g raw garlic or 33.4 g garlic components for 7 years	Dose-dependent protective association between raw garlic and lung cancer	[43]
	5,033 patients with gastric cancer (aged 35-74 years)	Double-blind intervention study	Synthetic allitridum 200 mg daily and 100 µg selenium every other day for 1 month per year, for a total of 3 years	Protection from gastric cancer	[44]
	3,365 *H. pylori* positive volunteers, with participants and risk for gastric cancer	Placebo-controlled blinded randomized trial	200 mg aged garlic extract and 1 mg steam distilled garlic oil 2, twice daily for 7.3 years	Decreased incidence of gastric cancer and mortality	[45]
Cardioprotective effects	157 postmenopausal asymptomatic women	Placebo-controlled double-blind clinical trial	Garlic herbal preparation containing 500 mg isoflavonoid for 12 months	Suppression and prevention of atherosclerosis	[46]

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Tab. II. *Continues.*

Bioactivities	Subjects/ patients	Study design	Interventions and duration	Results	References
Cardioprotective effects	92 obese patients	Placebo-controlled randomized double-blind nutritional intervention	Daily intake of 400 mg of garlic extract for 3 months	Suppressed inflammation and improved endothelial biomarkers of cardiovascular problems	[24]
	60 patients with mild hypercholesterolemia	Randomized controlled trial	6 g of aged black garlic twice a day for 12 weeks	Enhanced cardioprotective effects, beyond gold standard medication	[47]
	55 patients with metabolic syndrome	Randomized double-blind study	AGE 2400 mg daily for 52 weeks	Decreased low attenuation plaque (LAP) formation in coronary arteries	[48]
	51 coronary heart disease patients	Placebo-controlled randomized double-blinded study	150 mg Allicor garlic tablet 2 times per day for 12 months	Significant reduction in cardiovascular risk, by 1.5-fold in men ($p < 0.05$) and 1.3-fold in women	[49]
Antihypertensive effects	100 hyperlipidemic patients	Randomized study	Mixture of garlic and coriander, 2 g daily for 60 days	Improved lipid parameters and reduced blood pressure	[50]
	79 patients with uncontrolled systolic blood pressure	Dose-response trial	AGE 240/480/960 mg containing 0.6/1.2/2.4 mg of S-allylcysteine daily for 12 weeks	Marked reduction in systolic blood pressure	[51]
	41 moderately hypercholesterolemic patients	Double-blind crossover study	AGE 7.2 g daily for 10 months	Reduced systolic and diastolic blood pressure	[52]

amino acids. Protein extracts from soybeans are used as an alternative to meat [53]. In addition, legumes are rich in phosphorus, potassium, chromium, copper, selenium, zinc, magnesium, and folic acid, which have numerous health benefits, like cell growth, energy production, nerve and muscle function [54, 55].

Consuming legumes in moderate proportions and as part of a balanced diet has been observed to reduce the risk of hypertension, type 2 diabetes, obesity, cardiovascular diseases, stroke, and dislipidemia [56-58]. The low glycemic index of legumes and the presence of many non-nutrient phytochemicals (such as saponins, phytosterols, lectins, phytoestrogens, phytates, and amylase and trypsin inhibitors) confer several health benefits to legume consumers, such as an enhanced protection against cancer, free radicals-induced damage, cardiovascular diseases, and hypercholesteremia [59].

Moreover, legumes reduce oxidative stress, promote gut microbial diversity, colon health, and suppress inflammatory conditions and cancer [57-60]. The non-nutrient content of legumes, previously considered as hazardous to health, has now been proven to be important from a nutraceutical point of view. The health benefits of some non-nutrient compounds found in legumes is presented in Table III.

Clinical studies on legume consumption

Clinical studies have shown legumes to be useful in lowering blood sugar levels. For instance, in a randomised study 121 subjects having type 2 diabetes were given low-GI diet, containing one cup/day or ~ 190 g of cooked legumes or wheat fibre foods for 3 months: the results indicated that the patients that were given legumes had considerably decreased triglyceride levels, systolic and diastolic blood pressure, A1C, and blood glucose levels [70].

Similarly, regular consumption of legumes was shown to reduce total and low-density lipoprotein (LDL) cholesterol levels. A meta-analysis study reviewing 10 randomized, controlled trials based on non-soy legumes consumption for a minimum of 3 weeks resulted in lowered cholesterol levels in the participants. In another trial, 31 subjects having type 2 diabetes were given a legume-free therapeutic diet for heart disease. Alternatively, they were given the same diet but replacing red meat with legumes thrice a week. The results showed promising decreases in triglycerides, LDL cholesterol, fasting blood glucose, and insulin levels [71].

Being rich in minerals, potassium, magnesium, and fibre, legumes play a positive role in managing high blood pressure [72]. For instance, marked reductions in triglyceride levels, blood pressure, waist circumference

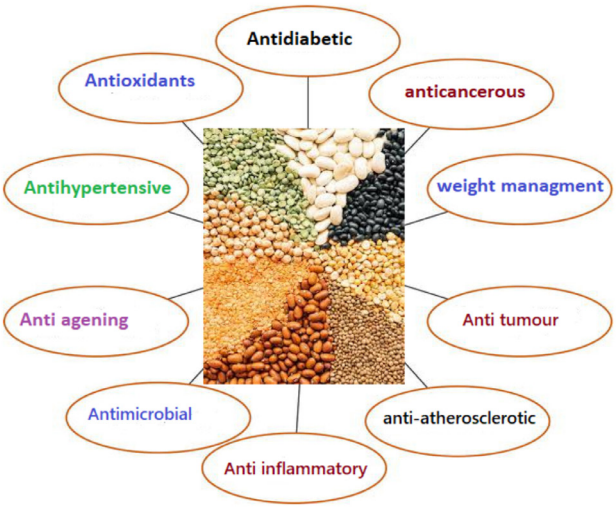
Tab. III. Bioactive compounds of legumes and their bioactivity.

Classification	Bioactive compounds	Sources	Bioactivity	References
Total phenolics	Gallic acid, protocatechuic acid, syringic acid, p-Hydroxybenzoic acid, vanillic acid, trans-p Coumaric acid, phydroxybenzoic acid, ferulic acid, sinapic acid	Adzuki bean, mung bean, kidney bean, white lupine, soybean, chickpea, red lentils	Antioxidant, anti-inflammatory, antihypertensive, anti-atherosclerotic, antitumor, ACE inhibitor, and antidiabetic and antiaging activities	[61- 64]
Saponins	Azukisaponin IV, VI, V, II, I, and azukisaponin III, soyasaponin and saponin B	Adzuki bean, mung bean, peas	Capture free radicals and stimulate antioxidant enzymes	[65]
Proanthocyani-dins	Procyanidins, prodelphinidins, rhamnosides	Mung bean	Antioxidant, tyrosinase inhibitor	[66]
Anthocyanins	Delphinidin-glucoside, cyanidin-galactoside, cyanidin-glucoside, pelargonidin-glucoside	Black soybean, red kidney bean	Antioxidant, antimicrobial anti-inflammatory, and antidiabetic	[63, 64]
Tocopherols	δ-Tocopherol, β,γ tocopherols	Soybean, black soybean, white kidney bean, cowpea, whole bean, kidney bean, black-eyed and pinto bean	Antioxidant and anticancer	[63, 64]
Carotenoids	Lutein and zeaxanthin isomers	Lentil, red kidney bean, cowpea	Antioxidant properties	[64]
Flavonoids	Catechin, epicatechin, quercetin-3-oglucoside, myricetin, kaempferol-3-orutinoside and kaempferol-3-o-glucoside, quercetin	Soybean, chickpea, mung bean, red lentils, kidney bean, black soybean, black turtle bean	Antioxidant properties	[67, 68]
Condensed tannins	Catechins	Lentil, black soybean, black turtle bean, adzuki bean, mung bean	Antioxidant, antimicrobial, anti-HIV, and anti-tumour activities	[69]

and weight were observed in 113 obese people consuming 1:2 ratio of legume servings to whole grains for 18 months [73]. Meta-analysis of the results of eight trials with more than 500 participants, 50% of which were obese or overweight, concluded significant reductions in systolic and mean arterial blood pressure in subjects who consumed a cup of legumes daily for 10 weeks [74]. In addition, people who consume legumes regularly tend to have lower body mass indices (BMI > 30 kg/m2) as compared to non-consumers [75]. This provides substantial evidence that a Mediterranean-style eating plan, characterised by daily consumption of legumes, is effective for weight loss [76].

Despite their numerous health benefits (Fig. 1), legumes are still not consumed at an optimum level in various areas of the world. This adds to the fact that, despite being the healthiest dietary pattern, the Med Diet is still restricted mainly to its region of origin. Developing healthy dietary programs and creating awareness would help people reap the full benefits of the typical spices, herbs, and other constituents of the Med Diet.

Fig. 1. Health benefits of legumes.



Conclusion

Traditional diets, such as the Med Diet, are not only budget friendly but also rich in healthy nutrients that provide an overall healthy lifestyle, with reduced risk of chronic and life-threatening diseases such as CVDs and cancer. Being rich in beneficial phytochemicals, garlic and legumes should be included in daily meal plans: these cardioprotective, anti-cancerous, antidiabetic and antihypertensive ingredients in our food will not only satisfy our culinary demands, but also promote a healthy life.

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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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