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 over time 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
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, anti-hypertensive, 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, allyl methyl-, 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 disulphides (DADS), Diallyl sulfides (DASI), Diallyl trisulphides (DATS), sulfur dioxide, E/Z-ajoene, S-allyl-cysteine (SAC), and S-allyl-cysteine sulfoxide (alliin), S-allyl mercapto cysteine (SAMC) | SAC AND SACM 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]   |
|                        |                     | Vinylidathins including 2-vinyl-4H-1,3 dithien                                      | 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 queretin | Scavenge free radicals, relax coronary arteries, prevent myocardial           | Antioxidants, cardioprotective effects                   | [17, 18]   |
| Non-sulphur containing saponins |                  | β-cholorogenin, diosgenin, desgalactotigomin-rhamnose, proto-desgalactotigomin-rhamnose, voghieroside D1, sativoside B1-rhamnose, and sativoside R1 gitogenin and proto-desgalactotigomin | 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, chick-

| Bioactivities   | Subjects/ patients | Study design                                                                 | Interventions and duration | Results                                                                 | Reference(s) |
|-----------------|--------------------|-------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------|--------------|
| **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 random double-blind parallel intervention study | 2.56 g aged garlic extract (AGE) per day for 90 days                  | Improved immune system function, less cold and flu symptoms | [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 HbA1c and fasting blood glucose levels | [36]     |              |
| 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 HbA1c 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 55-74 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]       |
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.

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**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 triglyceride levels, systolic and diastolic blood pressure, A1C, and blood glucose levels [70].

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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 | ACE 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 hyperlipidic 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 | ACE 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 | ACE 7.2 g daily for 10 months | Reduced systolic and diastolic blood pressure | [52]       |
and weight were observed in 113 obese people consuming a 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.

### 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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**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, phytodihydrobenzoic acid, ferulic acid, sinapic acid | Adzuki bean, mung bean, white lupine, soybean, chickpea, red lentils | Antioxidant, anti-inflammatory, antihypertensive, anti-atherosclerotic, antitumor, ACE inhibitor, and anti-diabetic and anti-aging activities | [61 - 64] |
| Saponins           | Azukiisaponin IV, VI, V, II, I, and azukiisaponin III, soyasaponin and saponin B     | Adzuki bean, mung bean, peas                 | Capture free radicals and stimulate antioxidant enzymes                                        | [65]       |
| Proanthocyanidins  | 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 anti-diabetic                                | [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-glucoside, myricetin, kaempferol-3-crutinoside 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, adzuki bean, mung bean | Antioxidant, antimicrobial, anti-HIV, and anti-tumour activities                              | [69]       |
Acknowledgements

This research was funded by the Provincia Autonoma di Bolzano in the framework of LP 15/2020 (dgp 3174/2021).

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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