

# The Antioxidant Properties of Greek Foods and the Flavonoid Content of the Mediterranean Menu

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**Abstract:** The Mediterranean diet is currently attracting interest because of its health benefits that may be due, in part, to the high content of this diet in antioxidant phytochemicals. The variety and amount of phytochemicals taken with the consumption of primary and composite foods of the Mediterranean diet may provide better antiatherogenic properties than single phytochemicals.

Flavonoids are the most important group of plant antioxidants. The Mediterranean diet is characterized by high intake of olive oil, fruit, vegetables, cereals, and legumes, some of which are good sources of flavonoids. Flavonoids consist of six principal classes: flavones, flavonols, flavan-3-ols, flavanones, anthocyanidins and isoflavones. The flavonoid intake from a traditional Greek plant-based weekly menu was calculated and the daily average flavonoid intake was found 118.6 mg/d, of which flavanones contribute 32% (38.5 mg/d), catechins (the most important group of flavan-3-ols) contribute 28% (32.7 mg/d), flavonols 22% (26.4 mg/d), anthocyanidins 9% (11 mg/d), flavones 8% (8.7 mg/d) and isoflavones contribute 1% (1.3 mg/d). Herbs and spices, which are commonly used in the traditional Greek cuisine, although added in small quantities, significantly contribute to the flavonol and flavone intake due to frequent consumption. The Greek version of the Mediterranean diet with its high consumption of fruit and vegetables is characterized by high intake of flavonoids in comparison to diets in northern European countries.

**Key Words:** Mediterranean diet, flavonoids, flavones, flavonols, flavan-3-ols, flavanones, anthocyanidins, isoflavones.

## INTRODUCTION

Plato, one of the most important philosophers of Greek antiquity, whose teachings extended to almost every single field of human knowledge including the human diet, is known to have said that a moderate and healthy diet, consists of cereals, legumes, fruit, milk, honey and fish. In contrast, meat, confectionery and wine should be consumed only in moderate quantities. As a whole, Plato's writings represent a valuable introduction for the study of the traditional Mediterranean diet [1].

The Mediterranean diet and lifestyle were shaped by climatic conditions, poverty and hardship, rather than by intellectual insight or wisdom. Since the 1950s [2] and particularly during the last 15 years [3-6] the Mediterranean diet is frequently being considered as a prototype for dietary recommendations. It is currently attracting major interest because of its health benefits that may be due, in part, to the high content of this diet in antioxidant phytochemicals [7].

The Mediterranean diet is characterized by a high consumption of fruit, vegetables, legumes, and non-refined cereals, a frequent consumption of fish, a moderate intake of alcohol, mainly wine during meals, a moderate consumption of milk and dairy products, mostly in the form of cheese and yogurt, and a low intake of meat and meat products. The

Mediterranean diet is rich in monounsaturated fatty acids due to the liberal use of extra virgin olive oil. It is also characterized by high content of fiber, vitamins, minerals and natural antioxidants, while the content of polyunsaturated, saturated, and hydrogenated lipids is low [6, 8].

Direct evidence in support of the beneficial properties of the Mediterranean diet has come from studies [5-6, 9-11] which have used a diet score, devised a priori on the basis of the desirable key features of the traditional diet common in the Mediterranean region. It was found that a diet that adheres to the principles of the traditional Mediterranean one is associated with a significant reduction in total mortality, even though no strong associations with mortality were evident for each of the components of the Mediterranean-diet score. This finding strengthens the hypothesis that the Mediterranean diet should be considered as an entity and there could be potential biologic interactions among its different components.

## BENEFICIAL COMPONENTS OF THE MEDITERRANEAN DIET

The composition of the Mediterranean diet favors foods with antioxidant potential, but the overall diet includes other cardioprotective characteristics, such as reduced saturated fats and greater use of unsaturated lipids, particularly from olive oil. The formation of an antioxidant hypothesis stimulated experimental and epidemiological studies on the possible role of antioxidants in the protection from coronary heart disease (CHD) and cancer. The health benefits of the Mediterranean diet are probably associated with several of

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its components, including high intake of olive oil, fruit, vegetables, cereals, and legumes, all of which are good sources of antioxidants.

It is generally acknowledged that flavonoids are the most important group of plant antioxidants because of their powerful antioxidant as well as anti-mutagenic and anti-proliferative properties *in vitro* [12]. Flavonoids consist of six principal classes: flavones, flavonols, flavan-3-ols, flavanones, anthocyanidins and isoflavones. These phenolic compounds occur ubiquitously in several components of the Mediterranean diet, particularly fruit, vegetables and legumes. Therefore, emerging evidence points to flavonoids as one of the preventative factors of the traditional diet of the Mediterranean populations.

### High Consumption of Olive Oil

Olive oil is the principal source of added lipids in the Mediterranean diet. Virgin olive oil is a natural product that is low in saturated fatty acids and high in monounsaturated fatty acids. In addition, it contains a balanced amount of essential fatty acids (linoleic and linolenic acids) that are adequately protected by natural antioxidants [13]. While most vegetable oils are extracted from oilseeds using solvents, olive oil is obtained from the whole fruit by means of physical pressure (cold pressed) without the use of organic solvents and can be consumed without further treatment. During cold pressing many of the components of the drupe are transferred to the oil, while antioxidants in oilseeds are greatly reduced during the various stages of refining [14-15].

Olive oil consists of major and minor components. The major components, including glycerols, represent more than 98% of the total oil weight. Minor components amount to about 2% of the total oil weight and include more than 230 chemical compounds, e.g. aliphatic and triterpenic alcohols, sterols, volatile compounds and antioxidants, mainly carotenes and phenolic compounds among which are lipophilic and hydrophilic phenols [16]. While the lipophilic phenols, including tocopherols, can be found in other vegetable oils, some hydrophilic phenols found in virgin olive oil are not generally present in other added lipids. The prevalent classes of hydrophilic phenols found in virgin olive oil are phenolic alcohols, phenolic acids, flavonoids, lignans and secoiridoids [16]. Phenolic acids, phenolic alcohols and flavonoids occur in many fruit and vegetables belonging to various botanical families, but secoiridoids are present exclusively in plants of the *Oleaceae* Family that includes *Olea europaea* L., from which olive oil derives. The main secoiridoids representatives in virgin olive oil are oleuropein and the aglycone of ligstroside [17].

Phenolic compounds, e.g. hydroxytyrosol and oleuropein, in extra virgin olive oil are responsible for its peculiar pungent taste and for its high stability to oxidation. Evidence is accumulating that olive oil phenolics are powerful antioxidants, both *in vitro* and *in vivo* [18]. *In vitro*, catecholic compounds such as oleuropein and hydroxytyrosol exert potent antioxidant activities, including inhibition of low density lipoproteins oxidation and free radical scavenging. Most important, recent data demonstrate that oleuropein and hydroxytyrosol are dose-dependently absorbed by humans and rats and, even at very low doses,

maintain their antioxidant activities *in vivo*. It was demonstrated that high quality, phenol-rich olive oil provides bio-active compounds that exert salubrious effects in humans and thus may contribute to the beneficial properties of the Mediterranean diet [19]. High consumption of such an olive oil could convey protection against cancer, CHD, and aging by inhibiting oxidative stress. Thus, the unique profile of the phenolic fraction, along with high intakes of squalene and oleic acid, may contribute to central, health-promoting compounds in virgin olive oil [17].

Extra virgin olive oil plays a primary role in the traditional Greek diet. Its significance is not only due to its beneficial properties but also to the fact that olive oil supports the consumption of a considerable quantity of vegetables and legumes. In the traditional Greek diet, the total lipid intake is high, up to 40% or even more of the total energy intake. In contrast, intake of both saturated and trans fatty acids is very low in Mediterranean countries [20].

### High Consumption of Vegetables and Fruit

It has long been recognized that the consumption of large amounts of vegetables and fruit can bring substantial health benefits [21]. Besides dietary antioxidants such as tocopherols, ascorbic acid and carotenoids, the polyphenolic compounds of plant origin are thought to exert favorable effects on cardio-protective mechanisms. Pre-eminent amongst the antioxidants in vegetables and fruit are flavonoids. There is considerable evidence that flavonoids can affect in a beneficial way, the occurrence of cancer and CHD [22-25]. Thus, antioxidants are likely mediators, at least in part, of the benefit derived from consumption of vegetables and fruit, and inferentially, the Mediterranean Diet.

Flavonoids are regarded as one of the most widespread groups of natural constituents found in plants. The physiological effects in humans are not yet completely understood, but the prevailing theories are based on the function of flavonoids as antioxidants and free radical scavengers [26-29]. Flavonoids consist of six principal classes: flavones, flavonols, flavan-3-ols, flavanones, anthocyanidins and isoflavones.

In the traditional Greek diet, the consumption of vegetables includes the various wild greens which are collected throughout Greece and are usually prepared with virgin olive oil. The Greek edible flora was found to contain high quantities of antioxidant compounds [30]. It would have been impossible to consume large quantities of them, however, if it were not for the olive oil that makes them not only edible, but in fact delicious. The prominent flavonol in the wild greens investigated is quercetin, followed by kaempferol. Nevertheless, while each individual green seems to contain a significant quantity of only one flavonoid subgroup, flavonol or flavones, composite green dishes such as green pies, contain significant quantities of a variety of flavonoids [30].

Wild greens are central to the Greek traditional diet and they have generally been overlooked as minor or trivial constituents. However, recent findings of their high flavonoid content and their potential health benefits indicate

their significance in the daily diet of the Mediterranean populations, since it has been demonstrated that popular herb extracts of Greece have a high antioxidant capacity against lipid peroxidation [31]. Thus, the combination of wild greens with olive oil may contribute to the apparently healthy promoting effects of the Greek diet.

Individual components of vegetables and fruit may not adequately explain their protective role; we also need to consider interactions among these components as well as the physical properties of these foods. It is for this reason that nutrition policy makers recommend the daily consumption of a variety of vegetables and fruit, rather than specific ones rich in particular compounds [32].

### High Consumption of Legumes

Another important component of the Mediterranean diet is the high consumption of legumes. The legumes consumed in the Greek diet, mainly include beans (*Phaseolus vulgaris*), lentils (*Lens culinaris*), and chick peas (*Cicer arietinum*). These legumes are frequently consumed as the main course, in the form of soups, especially on fasting days. Split chicklings (*Lathyrus sativus*) and fava beans (*Vicia fava*), are also frequently consumed.

Many micro-nutrients present in legumes, such as anthocyanins (glycosides of anthocyanidins), lecithin, and trypsin inhibitors have been suggested to have anticarcinogenic effects [33-34]. Legumes are excellent food sources of isoflavonoids and anthocyanidins. Anthocyanidins are flavonoids that seem to play an important role in preventing human diseases associated with oxidative stress [34]. It has recently been suggested that anthocyanidins might be one of the agents responsible for the protective barrier against DNA damage caused by highly reactive free radicals, indicating that leguminous plants might affect genetic integrity [33-34]. Antimutagenic effects also have been attributed to phenolic compounds of legumes, suggesting that the latter can function as health-promoting foods [34-35]. Moreover, legumes are a source of phytoestrogens, mainly genistein and daidzein, which are thought to have beneficial properties [36].

Beans correspond to 50% of the daily legume availability in Greece [37]. Condensed tannin fractions (proanthocyanidins) and pure flavonoids isolated from *Phaseolus vulgaris* displayed high antioxidant activity, indicating that these polyphenols, although they cause digestibility problems, may also be important dietary antioxidant sources with beneficial health effects [38-39]. Anthocyanidin pigments isolated from *Phaseolus vulgaris* have shown considerable antioxidative, radical scavenging, and inhibitory effects on lipid peroxidation [40]. There is an increased interest in the antimutagenic/antigenotoxic protective action of beans, which could be attributed not to one but to various compounds present in these leguminous plants [34-35].

In Greece, dry legumes are usually prepared with onions, herbs and leafy vegetables, which may also provide other classes of antioxidants. They are always cooked with olive oil, thus leading to a composite dish containing a mixture of antioxidants.

### High Consumption of Non-Refined Cereals

The traditional Mediterranean diet, at least in Greece, is characterized by high consumption of non-refined cereals, mainly in the form of whole-meal bread. Grains contain unique phytochemicals that complement those found in fruit and vegetables. These phytochemicals consist of various classes of phenolic compounds including flavonoids, phytoestrogens of the lignan family, phytates and several phenolic acids with antioxidant properties. They also contain tocotrienols and tocopherols. Some of these phytochemicals, such as ferulic acid which is the most common phenolic acid in cereal cell walls, are predominantly found in grains, whereas they are not present in significant quantities in fruit and vegetables [41-42]. Ferulic acid and its conjugates have antioxidant properties and their concentrations in grains is high [43].

While fruit and vegetables have most of their phytochemicals in free or soluble conjugate forms as glycosides, grains have most of their phytochemicals in the insoluble forms, bound to cell wall materials. Since most grain phenolics occur in the outer layers and the milling of grains removes essential nutrients, dietary fiber and many bioactive substances, refined grains are largely phytochemically depleted and nutritionally inferior to whole grains [41-42].

Grains contain a wide array of phytochemicals that may exert health benefits in humans through various mechanisms including antioxidant actions and mediation of hormones. Whole grain intake has been reported to be associated with reduced risk of colorectal cancer, CHD, diabetes, and even total mortality [41-42, 44]. These beneficial effects have been attributed to the unique, bound phytochemicals of grains. Lignans and phytoestrogens in grains may reduce the risk of hormone-related diseases such as prostate and breast cancers [45]. Moreover, increased consumption of whole grains has been recommended to improve insulin sensitivity and to lower serum insulin concentrations [46-47].

Whole grain products, because of their physical form and high content of fiber, tend to be slowly digested and absorbed and, thus, have relatively low glycemic indices [48]. Refined cereals have a higher rate of digestion than do whole-grain cereals, causing glycemic overload and compensatory increases in plasma concentrations of insulin and insulin-like growth factor I [49]. A diet high in phytochemicals from whole and unrefined foods can induce a protective altering of the lipoprotein profile and an improvement in levels of oxidative enzymes and large bowel function [50].

Therefore, whole grains compared to refined grains, are recommended for better health and their beneficial effects are more evident when their consumption is complemented with a high fruit and vegetable intake, as in the dietary pattern of the traditional Mediterranean diet.

### Frequent Consumption of Fish

Frequent fish consumption is an integral element of the traditional diet of the populations in the Mediterranean basin, since proximity to the sea accommodated the development of fishery. Major interest in the beneficial effect of fish

consumption was instigated in 1953, when investigations found surprisingly low cardiovascular disease (CVD) mortality in Eskimos consuming a traditional diet rich in eicosapentaenoic (20:5n-3) and docosahexaenoic (22:5n-3) acids. Recent research has shown an inverse correlation between consumption of fish and CVD events [51-55].

The nutritional benefits of fish consumption may relate to the provision of proteins of high biological value, minerals (Ca, Fe, Se, Zn) and vitamins (A, B<sub>3</sub>, B<sub>6</sub>, B<sub>12</sub>, E). Fish is a good source of omega-3 polyunsaturated fatty acids, an adequate intake of which may reduce the risks of CVD, hypertension and stroke [56-57] and lung cancer [58]. Omega-3 polyunsaturated fatty acids are essential nutrients for growth and development and for proper function of organs such as the eye and brain. They may also have an important role in attenuation of inflammatory processes [57, 59]. It has also been reported that increased consumption of fish is associated with a decrease in the prevalence of depression [60].

Based on research findings, guidelines have been issued recommending that healthy adults should eat at least two servings of fish per week, particularly fatty fish [61]. Although fish is a poor source of antioxidants, frequent consumption may play an important role in the health benefits of the Mediterranean diet.

### **Moderate Intake of Alcohol**

One of the key elements of the Mediterranean diet is the moderate consumption of wine, usually taken with meals. Moderate consumption of alcohol is inversely associated with CVD risk [62-65]. The role of wine in protecting against CVD involves not only an increase of high density lipoprotein cholesterol but also reduction of oxidative damage to plasma lipoproteins [66]. The cardio-protective effect of the regular consumption of wine has been linked to its polyphenolic compounds, which are antioxidants, free radical scavengers and inhibitors of lipid peroxidation processes [67-69].

The polyphenolic antioxidants are important contributors to the wine's flavor and fragrance [70]. The variety and concentration of polyphenols is higher in red wine than in white wine. Most common antioxidants in red wine are the polyphenolic phytoestrogen resveratrol, the flavonoids catechin, epicatechin, quercetin and procyanidins, and phenolic acids such as gallic acid, which regulate major pathways in lipoprotein metabolism [68-69]. Tyrosol and caffeic acid are found in white wine, and they have been evaluated for their effect on oxidative stress and inflammatory reactions [71]. The traditional Greek diet is associated with moderate consumption of red wine and white wine, the latter in the form of retsina (wine flavoured with pine resin).

Most wine phenolic compounds can also be found in other plant foods, but red wine seems to be the only major dietary source of resveratrol. Resveratrol exerts powerful anti-inflammatory effects, that may contribute to the cardio-protective effects associated with regular consumption of red wine [72]. It has been shown that resveratrol is the most efficiently absorbed polyphenol. Its *in vitro* biologic

activities, that may be relevant to protection against cancer, inflammation and atherosclerosis, cover a wider spectrum and seem to be more potent than those of virtually any other polyphenol tested. Its concentration in the wine is equivalent to that of quercetin and to about one fifth of that of catechin. But since resveratrol is absorbed five times more effectively than catechin, it is probable that equal concentrations of their metabolites will accumulate in human blood after consumption of a typical red wine [73].

There is evidence that wine procyanidins are active in preventing lipid oxidation of foods while in the digestive tract, thus preventing the postprandial plasma rise in oxidants [66]. Therefore, the fact that in the Mediterranean diet wine consumption is usually taken with meals, could limit the formation and absorption of products of oxidation from the gut. Further research on this issue is needed [70].

### **Low Consumption of Milk and Dairy Products**

Milk, cheese and yogurt are important contributors to the dietary intake of calcium, and they are also significant contributors to the intakes of riboflavin (vitamin B<sub>2</sub>) and vitamin B<sub>12</sub>. Generally, dairy products are considered a source of saturated fatty acids, the principal dietary source of conjugated linoleic acid and a major source of trans-fatty acids and cholesterol [74].

A strong ecological correlation has been reported between milk consumption and CHD death rate [75-76]. The correlation was said to be stronger with some dairy products than with others. It was strong with whole milk, weaker with butter and near zero with cheese. As the main effect of fermentation on milk is the conversion of lactose into lactic acid, lactose emerged as a possible atherogenic agent [77].

Lactose when digested yields galactose, which has been implicated in oxidation of lipoproteins associated with atherosclerosis and coagulation [75]. Lactose is destroyed during fermentation, which would explain why yogurt and cheese are not correlated with CHD deaths. It may also explain why lactose intolerance patients, who have a low lactose consumption, also tend to have lower rates of CHD [78]. The oxidation induced by lactose seems likely to be inhibited by wine antioxidants, which protect the coronary artery. Wine phenolics, by interfering with the generation of oxidised lipoproteins, would protect against some of the allegedly damaging effects of milk. A similar protective effect should be derived from fruit and vegetables containing the same phenolics [75, 79]. Therefore, several elements of the traditional Mediterranean diet, such as high fruit and vegetable intake and moderate wine consumption, would be beneficial in this speculative context.

There are other milk components, besides lactose, that have also been linked to CHD. The association between saturated fat intake and risk of atherosclerosis is well established [80-81], while it appears that other non fat aspects of milk, such as the Ca / Mg ratio and milk fat-globule membrane antigens, are also possible atherogenic agents [75]. Another theory connecting non-fat milk components with CHD is that animal proteins contribute to production of homocysteine, which plays an important role in the development of atherosclerosis [76].

With respect to possible associations between consumption of dairy products and cancer, results are equivocal and no firm judgement can be made. Dairy products contain both components that have been hypothesized to increase the risk of cancer, and components that have been hypothesized to reduce the risk of cancer, e.g. saturated fats have been linked to increased risk of lung [82] and prostate cancers [83], whereas conjugated linoleic acids have been reported to reduce the risk of breast cancer [84-85]. Consumption of milk has been reported to raise serum levels of insulin-like growth factor-I, which in turn may increase cancer risk [86]. As indicated, current knowledge concerning consumption of dairy products in relation to cancer risk is still limited.

Regarding yogurt, a beneficial effect on health, an improvement of the immune system and a reduction of colon cancer risk have been reported [87]. Yogurt, and the lactic acid producing bacteria that it contains, have received attention as potential cancer-preventing agents in the diet [88]. The Mediterranean diet is characterized by a moderate or low consumption of milk and dairy products, mostly in the form of cheese and yogurt. It appears that this dietary pattern allows the favorable effects derived from consumption of dairy products, while other elements of the diet, notably fruit and vegetable intake and moderate wine consumption, may block dairy products-related unfavorable effects.

#### Low Intake of Meat and Meat Products

Red meat, which is a natural source of conjugated linoleic acid, has been linked to an increased risk of colorectal cancer [89-90]. Processed meat and highly cooked meat have also been reported to increase the risk of this cancer [91-92]. Nevertheless, totally excluding meat from the diet is not recommended, since this could lead to increased risk of nutritional deficiencies, in particular deficiencies of vitamin B<sub>12</sub>, vitamin B<sub>2</sub> and several minerals, such as Ca, Fe and Zn [93].

Red meat has been thought to increase colorectal cancer risk through the effects of fat, dietary haem, protein and in the case of processed meat, N-nitroso compounds [94-96]. Additionally, cooking meat at high temperatures (e.g. frying or grilling) can result in the formation of heterocyclic amines (HCA) from creatinine, amino acids, and sugar [97]. These compounds have been shown to have high mutagenic activity [92]. Polycyclic aromatic hydrocarbons (PAH) have also been found in barbecued meat and fish in variable amounts, depending on the type of heat source used. PAH may be involved in carcinogenesis [91]. Moreover, N-nitroso compounds found in processed meat products have been positively associated with risk of pancreatic cancer [98].

It is not clear whether the mechanisms of increased cancer risk associated with meat intake involve animal fat, cooking methods, meat varieties or other factors. Study results are inconsistent and remain inconclusive [90]. Red meat has been reported to have different effects depending on its fat content [99-100], while in epidemiological studies a possible connection to the methods of meat preparation has been suggested [101]. The grilling/barbecuing and frying of meat can produce high levels of carcinogens such as HCA and PAH, while other methods of preparation, such as

baking or stewing lead to the formation of negligible levels of these compounds [102]. The fact that in the traditional Mediterranean diet, roasting and stewing are more frequently used and the consumption of meat eaten fried, grilled or barbecued is relatively low, is compatible with the somewhat lower incidence of cancer observed in the region [101, 103].

Although a high consumption of red meat, which is rich in haem iron and saturated fat, may increase the risk of CVD and some types of cancer, this does not necessarily apply to white meat and fish. Moreover, fruit and vegetable fibers which are abundant in the Mediterranean diet, have been found to have a protective effect on colon cancer [104]. A prudent omnivorous diet, such as the Mediterranean diet, with moderate amounts of animal products, in which red meat is partly replaced by white meat and fish, together with the consumption of ample amounts of unrefined plant products, is likely to be a health protective diet [93].

In conclusion, a complex combination of favorable nutritional elements may contribute to the observed health benefits of the Mediterranean diet. The complex mixture of phytochemicals in foods may provide better antiatherogenic and anticancer properties than single phytochemicals, through a combination of additive and/or multiplicative effects.

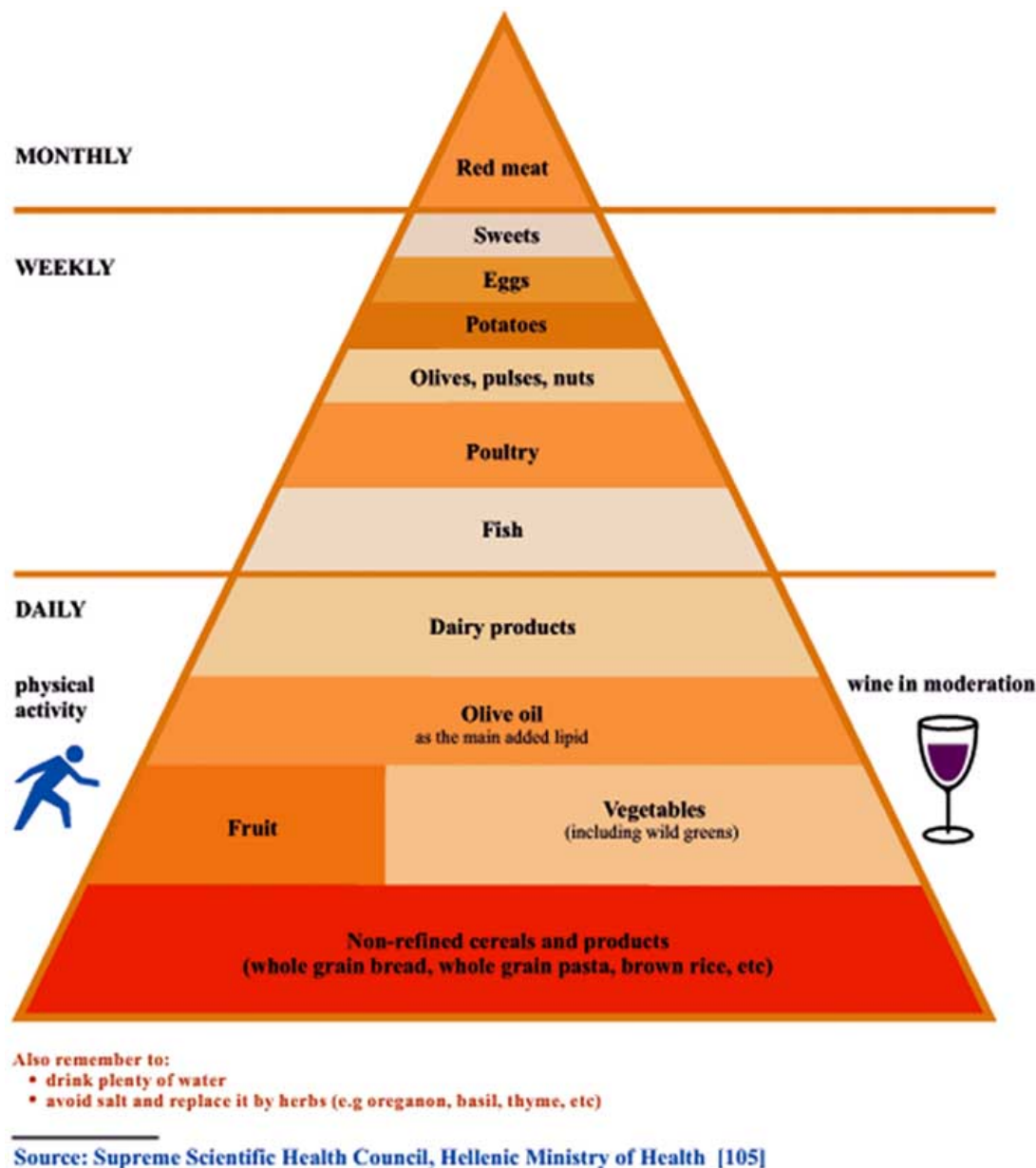
#### FLAVONOID INTAKE IN A TYPICAL MEDITERRANEAN MENU

We have calculated the intake of the principal food antioxidants, the flavonoids from a traditional Greek plant-based weekly menu. The specific flavonoids that have been investigated are: *flavones*: (luteolin, apigenin), *flavonols* (myricetin, quercetin, kaempferol, isorhamnetin), *flavan-3-ols (catechins)*: (+)-catechin, (-)-epicatechin, (-)-epigallocatechin, (-)-epicatechin gallate, (-)-epigallocatechin gallate, *flavanones* (eriodictyol, hesperetin, naringenin), *anthocyanidins* (cyanidin, delphinidin, malvidin, peonidin, petunidin) and *isoflavones* (daidzein, genistein). These flavonoids are most common in plant foods and have been investigated in connection with health diseases.

A weekly menu, representative of the traditional Greek diet, was designed on the basis of the traditional Mediterranean Pyramid depicted in Fig. (1) [105]. The investigated menu is presented in Table 1. It adheres to the religious habit of the traditional Greek family, which involves fasting every Wednesday and Friday. Portion sizes were defined according to the Greek market regulations and refer to edible parts.

The flavone, flavonol, flavan-3-ol, flavanone and anthocyanidin calculations were mainly based on the recently released USDA flavonoid database [106] with some exceptions<sup>1</sup>, while isoflavone calculations were based exclusively on data from the VENUS phytoestrogen database [107].

<sup>1</sup> Flavonoid calculations for olives, dill and oregano were based on unpublished data (97-DIATRO-30 Report- Hellenic General Secretariat of Research and Technology), while calculations for herbal tea ((*Sideritis*, Greek mountain tea) were based on personal communication [111].



**Fig. (1).** Mediterranean diet Pyramid.

The flavonoid content of raw salads was calculated by the breakdown of their components and the summing of the flavonoid content of all raw ingredients of the same species e.g. the quantity of raw onion from salads for the whole week amounted to 60g (Table 2). These amounts refer to raw salad ingredients, while the contribution of the same ingredients, e.g. onions, in composite foods is included in the recipe calculations. With respect to cooked composite foods, the flavonoid content of each recipe has been calculated separately taking into account the individual ingredients. Again the recipes have been broken down into components and the calculations were made in proportion to the contribution of each raw component and the portion size in the weekly Mediterranean menu. Flavonoid correction factors have not been applied, based on the observation that

flavonoid losses due to preparation are negligible (<10%), so that a correction of flavonoid levels due to losses from preparation is not necessary [24]. Preparation of foods causes a decrease in catechin concentrations [25], but since most catechin-containing foods are consumed raw, this is not likely to be an important determinant of catechin intake.

The results of the calculations of flavonoid intake are presented in Tables 2-5. Only the foods of the Mediterranean menu that contribute to the flavonoid intake are listed. Data presented in Tables 2-5 reflect weekly intakes, while results presented in this section refer to daily intakes. According to the calculations the daily average flavonoid intake of a typical Mediterranean menu is 118.6 mg/d, of which flavanones contribute 32% (38.5 mg/d), catechins contribute 28% (32.7 mg/d), flavonols 22% (26.4 mg/d), anthocy-

**Table 1. The Investigated Weekly Menu, Representative of the Traditional Greek Diet**

	Monday	Serve g	Tuesday	Serve g	Wednesday	Serve g	Thursday	Serve g	Friday	Serve g	Saturday	Serve g	Sunday	Serve g
<b>Breakfast</b>	Herbal tea	165	Yogurt	200	Herbal tea	165	Herbal tea	165	Herbal tea	165	Herbal tea	165	Herbal tea	165
	Sugar	5	Honey	40	Sugar	5	Sugar	5	Sugar	5	Sugar	5	Sugar	5
	Feta	50			Black olives	30	Feta	50	Black olives	40	Feta	50	Feta	50
	Bread	60			Bread	60	Bread	60	Bread	60	Bread	60	Bread	60
<b>Morning Snack</b>	Grapes	150	Apple	160	Apple	160	Apple	160	Apple	160	Apple	160	Apple	160
<b>Lunch</b>	Green beans	250	Fried wet salted cod	150	Lentils with tomato	350	Chicken casserole	180	Eggplants casserole	250	Baked vegetables	250	Roast lamb	110
	Feta	50	Chicories	290	Green olives	40	Rice (pilaf)	150	Fish roe salad	50	Feta	50	Baked potatoes	150
	Bread	90	Bread	90	Bread	90	Bread	90	Bread	90	Bread	90	Bread	90
	Red wine	120	Red wine	120	Red wine	120	Red wine	120	Red wine	120	Red wine	120	Red wine	120
	Apple	160	Pear	160	Orange	200	Pear	160	Orange	200	Pear	160	Orange	200
					Lettuce salad	140	Mizithra (cheese)	10					Lettuce salad	140
							Cabbage salad	120						
<b>Afternoon Snack</b>	Raisins	60	Olive oil cookies	40	Semolina cake (halvah)	65	Pasteli, sesame bar	30	Semolina cake (halvah)	65	Raisins	60	Olive oil cookies	40
	Greek coffee	86	Greek coffee	86	Greek coffee	86	Greek coffee	86	Greek coffee	86	Greek coffee	86	Greek coffee	86
	Sugar	6	Sugar	6	Sugar	6	Sugar	6	Sugar	6	Sugar	6	Sugar	6
	<b>Dinner</b>	Cheese pie	150	Spinach rice	250	Potatoes casserole	250	Feta	50	Spinach pie	155	Fried potatoes	115	Chilopites (pasta)
Greek salad		200	Feta	60	Lettuce salad	140	Greek salad	200	Greek salad	200	Greek salad	200	Cabbage salad	120
Bread		90	Bread	90	Bread	90	Bread	90	Bread	90	Bread	90	Bread	45
											Fried egg	56	Mizithra (cheese)	10

anidins 9% (11 mg/d), flavones 8% (8.7 mg/d) and isoflavones contribute 1% (1.3 mg/d).

Table 2 presents the weekly flavone and flavonol intake of the investigated menu. The majority of the flavone intake derives from apigenin (77%). Common herbs of the Greek culinary culture such as parsley are a good source of apigenin. In fact, parsley is the only source of apigenin derived from composite foods in the investigated menu. The calculated average daily apigenin intake of the studied

Mediterranean menu is 6.7 mg/d, with the main contributing food source being parsley (96%). The major contributor to the total flavone intake is parsley (74%), followed by black olives (18%).

The majority of the flavonol intake derives from quercetin (85%). Quercetin is considered the most widespread flavonoid as it is present in over half the ingredients in the Mediterranean menu. The main contributors to the total flavonol intake are apples (27%) and onions (21%). Other

**Table 2. Calculated Data\* on Flavone and Flavonol Intake of a Weekly Mediterranean Menu**

Food or recipe**	Amount	Flavones (mg/week)		Total	Flavonols (mg/week)				Total
		g/week	Apigenin		Luteolin	Isorhamnetin	Kaempferol	Myricetin	
<b>Apple, unpeeled</b>	1120	0,00	0,00	0,00		0,00	0,00	49,50	49,50
<b>Cabbage</b>	200	0,02	0,08	0,10		0,24	0,00	0,02	0,26
<b>Dill, fresh</b>	3	0,00	0,00	0,00	1,30	0,40	0,02	1,66	3,38
<b>Grapes</b>	150	0,00	0,00	0,00		0,00	0,68	1,31	1,99
<b>Herbal tea</b>	990	1,78	0,00	1,78	0,00	0,00	0,00	0,00	0,00
<b>Lemon juice, fresh</b>	20	0,00	0,00	0,00		0,00	0,01	0,06	0,07
<b>Lettuce</b>	300	0,03	0,00	0,03		0,12	0,06	5,85	6,03
<b>Olives, black</b>	126	0,00	11,29	11,29		0,00	0,00	6,65	6,65
<b>Onion</b>	60	0,00	0,00	0,00	1,15	0,11	0,00	7,96	9,22
<b>Oregano, dry</b>	4	0,00	0,00	0,00	0,00	0,00	0,00	1,32	1,32
<b>Pear, unpeeled</b>	480	0,00	0,00	0,00	1,44	0,00	0,00	2,02	3,46
<b>Spring onion</b>	42	0,00	0,00	0,00		0,65	0,00	5,98	6,63
<b>Tomato</b>	400	0,00	0,00	0,00		0,28	0,00	2,28	2,56
<b>Wine, red</b>	840	0,00	0,00	0,00	0,17	0,42	6,13	7,06	13,78
<i>Baked vegetables</i>	250	5,78	0,02	5,8	0,55	0,53	0,15	3,18	4,41
<i>Chicken casserole</i>	180	0,00	0,00	0,00	0,24	0,08	0,00	2,13	2,45
<i>Chilopites (pasta)</i>	250	0,00	0,00	0,00		0,08	0,00	0,68	0,76
<i>Eggplants casserole</i>	250	9,83	0,04	9,87	0,72	0,16	0,26	5,62	6,76
<i>Fish roe salad</i>	50	0,00	0,00	0,00	0,17	0,02	0,002	1,22	1,41
<i>Green beans, fresh</i>	250	13,51	0,06	13,57	0,75	1,28	0,36	13,34	15,73
<i>Lentils</i>	350				0,54	0,13		4,54	5,21
<i>Olive oil cookies</i>	80	0,00	0,00	0,00		0,00	0,01	0,02	0,03
<i>Potatoes casserole</i>	250	8,18	0,03	8,21	0,58	0,14	0,22	4,65	5,59
<i>Spinach pie</i>	155	7,85	0,75	8,6	1,98	1,91	0,25	10,97	15,11
<i>Spinach rice</i>	250	0,00	1,75	1,75	2,81	1,39	0,06	18,32	22,58
<b>Total</b>		46,98	14,02	61,00	12,40	7,94	8,21	156,34	184,89

\*Flavonoid calculations were based on data from the USDA flavonoid database [106], with the exception of olives, dill, oregano (unpublished data) and herbal tea [111]. Empty cells indicate that no information was available.

\*\*Recipes are presented in italics.

significant contributors are spring onions (10%), dill (8%), wine (7%) and spinach (6%). The calculations integrate ingredients from both salads and recipes.

The daily average flavonol and flavone intake is calculated at 35 mg/d. The corresponding intake in a Dutch population was 23 mg/d [108], which is in accordance with more recent estimations in a USA population [109]. Consequently, in the Mediterranean menu investigated, the flavonol and flavone intake is considerably higher. The contribution of isorhamnetin to the flavonol content of the investigated menu is approximately 2 mg/d. Isorhamnetin

content of foods is included in our calculations, but excluded from the Dutch population intake estimations [108], but the total flavonol and flavone content of the investigated menu remains higher than the Dutch one. The intake of flavonols and flavones by the Dutch population was calculated as 21 and 2 mg/d, respectively. The intake of flavonols and flavones in the Mediterranean menu is 26.4 and 8.7 mg/d, respectively, indicating the important contribution of herbs.

The most important flavonol source in the Dutch population intake was quercetin with a mean daily intake of 16 mg/d. The same is true for the Mediterranean diet, but in

this case the mean daily quercetin intake is 22.3 mg/d. In the Dutch population, tea beverages turned out to be the major source (48% of total intake), followed by onions (29%) and apples (7%). Similar results were obtained in the USA [109]. In the Mediterranean menu the main contributors to flavonol and flavone intake are apples (20%), parsley (19%) and onions (16%), followed by olives (7%), spring onions (7%), red wine (6%), dill (6%) and spinach (5%), indicating that in the Greek diet, flavonols and flavones derive from a wider range of foods. It is apparent that herbs such as parsley and dill, which are commonly used in traditional Greek dishes, although added in small quantities, significantly contribute to the overall flavonol and flavone intake because of frequent consumption. Typical Mediterranean foods such as olives and red wine also contribute substantially.

Table 3 presents the weekly catechin and flavanone intake of the investigated menu. The catechins, (-)-epigallocatechin and (-)-epigallocatechin gallate, were also investigated but are not presented in Table 3 since they did not contribute to the catechin content of the menu. The majority of the catechin intake derives from (-)-epicatechin (63%). The calculated average daily (-)-epicatechin intake of the studied Mediterranean menu is 20.7 mg/d, with the main contributing food source being again the apples (63%). However, with respect to total catechin intake, apples (44%) and red wine (44%) are equal contributors. The principal flavanone in Greece is hesperetin, estimated at 28.6 mg/d (74%). Oranges are the principal contributors (98%) to the total flavanone intake.

The daily average catechin intake is calculated at 32.7 mg/d. The corresponding intake in a Dutch population was found 50 mg/d [110]. Consequently, in the Mediterranean menu catechin intake is lower. In the Dutch population, black tea turned out to be the major source (reaching a

contribution of 87% of total catechin intake in elderly subjects), followed by apples/pears (6%) and chocolate (6%). In the Mediterranean menu the main contributors to catechin intake are apples and red wine. Herbal tea (*Sideritis*) did not contribute to the catechin intake in the Mediterranean diet, since it is a poor source of flavonoids [111]. However, the daily average catechin, flavonol and flavone intake of the Mediterranean menu is 67.8 mg/d, while the corresponding intake in a Dutch population was 58 mg/d [112], reflecting the fact that the Mediterranean menu is favored by a higher fruit and vegetable consumption.

With respect to flavanones, which are polyphenols specific of citrus fruit, the daily average hesperetin intake is 28.6 mg/d and the daily average naringenin intake 9.6 mg/d. These findings are in accordance with those of researchers in Finland [113]. However, in the Finnish population, the hesperetin and naringenin values correspond to 51% and 15% respectively of the total flavonoid intake, while in the Mediterranean menu they correspond to 24% and 8% respectively. This indicates that while the daily average intake of flavanones is similar, the Mediterranean diet is richer with respect to total flavonoid intake. The mean total intake of flavonols, flavones and flavanones in another Finnish population was 24.2 mg/d [114], while the corresponding intake in the Mediterranean menu is 73.6 mg/d, that is, substantially higher. This difference actually reflects the higher quercetin intake of the Mediterranean diet 22.3 mg/d, as opposed to 3.3 mg/d in the Finnish population diet.

Table 4 presents the weekly anthocyanidin and isoflavone intake of the investigated menu. The primary source of anthocyanidins is red wine (99.9%), while the primary source of isoflavones is brown bread (94%). The daily average anthocyanidin intake is 11 mg/d, deriving from

**Table 3. Calculated Data\* on Catechin and Flavanone Intake of a Weekly Mediterranean Menu**

Food or recipe**	Amount	Catechins (mg/week)			Total	Flavanones (mg/week)			Total
		g/week	(-)-Epicatechin	(-)-Epicatechin 3-gallate		(+)-Catechin	Eriodictyol	Hesperetin	
<b>Apple, unpeeled</b>	1120	91,17	0,00	10,64	101,81				
<b>Grapes</b>	150	1,53	0,65	3,70	5,88				
<b>Lemon juice, fresh</b>	20					0,98	2,40	0,29	3,67
<b>Orange</b>	600						196,38	66,90	263,28
<b>Pear, unpeeled</b>	480	15,22	0,00	1,25	16,47				
<b>Raisins</b>	120	0,85	0,00	3,56	4,41				
<b>Vinegar</b>	15	0,33			0,33				
<b>Wine, red</b>	840	36,04	0,00	63,92	99,96				
<i>Fish roe salad</i>	50					0,19	0,47	0,06	0,72
<i>Olive oil cookies</i>	80					0,02	1,21	0,22	1,45
<b>Total</b>		145,14	0,65	83,07	228,86	1,19	200,46	67,47	269,12

\*Flavonoid calculations were based on data from the USDA flavonoid database [106]. Empty cells indicate that no information was available.

\*\* Recipes are presented in italics.

**Table 4. Calculated Data on Anthocyanidin\* and Isoflavone\*\* Intake of a Weekly Mediterranean Menu**

Food or recipe***	Amount	Anthocyanidins (mg/week)					Total	Isoflavones (mg/week)		Total
		g/week	Cyanidin	Delphinidin	Malvidin	Peonidin		Petunidin	Daidzein	
Apple, unpeeled	1120							0,02		0,02
Bread, brown	1575							4,71	3,55	8,26
Raisins	120							0,07	0,15	0,22
Tomato	400								0,01	0,01
Vinegar	15	0,00	0,01	0,07	0,01	0,01	0,1			
Wine, red	840	2,27	5,71	47,71	9,83	11,68	77,2			
<i>Baked vegetables</i>	250							0,00	0,005	0,005
<i>Chilopites (pasta)</i>	250							0,01	0,01	0,02
<i>Eggplants casserole</i>	250							0,00	0,005	0,005
<i>Fish roe salad</i>	50							0,03	0,03	0,06
<i>Green beans, fresh</i>	250							0,03	0,08	0,11
<i>Lentils</i>	350							0,01	0,01	0,02
<i>Potatoes casserole</i>	250							0,00	0,01	0,01
<i>Semolina cake</i>	130							0,00	0,01	0,01
<b>Total</b>		2,27	5,72	47,78	9,84	11,69	77,3	4,88	3,87	8,75

\*Anthocyanidin calculations were based on data from the USDA flavonoid database [106]. Empty cells indicate that no information was available.

\*\* Isoflavone calculations were based on data from the VENUS phytoestrogen database [107]. Empty cells indicate that no information was available.

\*\*\* Recipes are presented in italics.

red wine, which is significantly lower than the estimated daily intake of 180 mg/d in the United States, mainly deriving from fruit and red wine [115]. However, no data were available in the USDA flavonoid database for many of the fruit included in the Mediterranean diet; therefore our results may underestimate the anthocyanidin content in the Mediterranean menu.

With respect to isoflavones, the daily average intake calculated is 1.3 mg/d, which is comparable with previously published isoflavone intake data in the Netherlands [116]. However, the results differ significantly with respect to the source of isoflavones. In the Mediterranean menu daidzein and genistein, derived from bread, correspond to 96 % and 92% of the total daily intake, while in the Dutch population, daidzein and genistein daily intake from bread corresponds merely to 15.4% and 11.8%, respectively. The main isoflavone sources for the Dutch population were peas/beans, breakfast cereals, nuts and coffee.

Table 5 presents the weekly total flavonoid intake of the investigated menu. With respect to overall daily flavonoid intake the major contributors are oranges 32%, red wine 23% and apples 18%, followed by parsley 6% and onion 5%. These results show that about 50% of the flavonoid intake of the Mediterranean diet derives from fruit consumption. With respect to recipes, flavonoids are present in vegetable dishes, with the highest content found in the fresh green beans recipe. The high flavonoid content of this recipe is due not

only to the contribution of its basic ingredient, the green beans, but also to the contribution of ingredients such as onions and parsley which are added in small amounts to flavour the dish.

### The Need for Further Research

The data presented in Tables 2-5 are merely indications of the flavonoid content of a typical plant-based Mediterranean menu, since seasonal variation of diet as well as flavonoid concentration of foods should also be taken into account. For the purpose of theoretically determining the flavonoid content of the Mediterranean menu, the USDA and VENUS databases were mainly used [106-107]. However, both databases consist of literature data from various sources obtained by different analytical methods. Current estimates of flavonoid intakes vary considerably, because food composition information with respect to flavonoids is incomplete [117]. However, in spite of the reservations involved in the theoretical determination, the indications show that the traditional Mediterranean diet has high flavonoid content, with the highest contributors deriving from oranges, red wine, apples, parsley and onion. The inclusion of herbs and spices in the traditional Greek cuisine, significantly contributes to the flavonoid content of the diet.

The investigated Mediterranean menu has a substantially higher flavonoid content in comparison to previous estimates of intakes of selected flavonoid subgroups [108, 112, 114].

Table 5. Calculated Data on total Flavonoid Intake of a Weekly Mediterranean Menu

Food	Amount	Total flavonoids	Recipe	Amount	Total flavonoids
	g/week	mg/week		g/week	mg/week
Apple, unpeeled	1120	151,33	Baked vegetables	250	10,21
Bread, brown	1575	8,26	Chicken casserole	180	2,45
Cabbage	200	0,36	Chilopites	250	0,78
Dill, fresh	3	3,38	Eggplants casserole	250	16,64
Grapes	150	7,87	Fish roe salad	50	2,19
Herbal tea	990	1,78	Green beans, fresh	250	29,41
Lemon juice, fresh	20	3,74	Lentils	350	5,23
Lettuce	300	6,06	Olive oil cookies	80	1,48
Olives, black	126	17,94	Potatoes casserole	250	13,81
Onion	60	9,22	Semolina cake	130	0,01
Orange	600	263,28	Spinach pie	155	23,71
Oregano, dry	4	1,32	Spinach rice	250	24,33
Pear, unpeeled	480	19,93			
Raisins	120	4,63			
Spring onion	42	6,63			
Tomato	400	2,57			
Vinegar	15	0,43			
Wine, red	840	190,94			
<b>Total</b>		699,67			130,25
<b>Weekly grand total (mg/week)</b>					829,92
<b>Daily intake (mg/d)</b>					118,6 mg/d

However, to our knowledge, earlier studies have not estimated the total flavonoid intake taking into account all six flavonoid subgroups. Our results indicate a daily flavonoid intake of 118.6 mg/d. Given that our data rely on a weekly menu typical of the dietary pattern of the Greek variant of the Mediterranean diet, and that the main flavonoid food sources such as fruit, vegetables, herbs, wine and bread are integral components of the Mediterranean diet, our results provide support for a role of antioxidants in the health benefits of the diet.

The Greek land offers its inhabitants a large variety of products of excellent quality and taste. The Greeks have exploited the gifts of nature and have created through the years a large range of foods with outstanding taste, attractive appearance and health promoting properties. This Mediterranean dietary pattern besides the quality and variety of primary foods, also involves the way that these ingredients are consumed through expert cooking practices that reflect the Greek culinary culture, perhaps even the Epicurean philosophy.

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## ABBREVIATIONS

CVD	=	CardioVascular Disease
CHD	=	Coronary Heart Disease
HCA	=	HeteroCyclic Amines
PAH	=	Polycyclic Aromatic Hydrocarbons

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