Omega-3 Fatty Acids and Antioxidants in Edible Wild Plants

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ABSTRACT

Human beings evolved on a diet that was balanced in the omega-6 and omega-3 polyunsaturated fatty acids (PUFA), and was high in antioxidants. Edible wild plants provide alpha-linolenic acid (ALA) and higher amounts of vitamin E and vitamin C than cultivated plants. In addition to the antioxidant vitamins, edible wild plants are rich in phenols and other compounds that increase their antioxidant capacity. It is therefore important to systematically analyze the total antioxidant capacity of wild plants and promote their commercialization in both developed and developing countries. The diets of Western countries have contained increasingly larger amounts of linoleic acid (LA), which has been promoted for its cholesterol-lowering effect. It is now recognized that dietary LA favors oxidative modification of low density lipoprotein (LDL) cholesterol and increases platelet response to aggregation. In contrast, ALA intake is associated with inhibitory effects on the clotting activity of platelets, on their response to thrombin, and on the regulation of arachidonic acid (AA) metabolism. In clinical studies, ALA contributed to lowering of blood pressure, and a prospective epidemiological study showed that ALA is inversely related to the risk of coronary heart disease in men. Dietary amounts of LA as well as the ratio of LA to ALA appear to be important for the metabolism of ALA to longer-chain omega-3 PUFAs. Relatively large reserves of LA in body fat, as are found in vegans or in the diet of omnivores in Western societies, would tend to slow down the formation of long-chain omega-3 fatty acids from ALA. Therefore, the role of ALA in human nutrition becomes important in terms of long-term dietary intake. One advantage of the consumption of ALA over omega-3 fatty acids from fish is that the problem of insufficient vitamin E intake does not exist with high intake of ALA from plant sources.

Key words: Alpha-linolenic acid, antioxidants, chronic diseases, edible wild plants, evolutionary aspects of diet, omega-3 fatty acids.

Abbreviations: AA: arachidonic acid; AI: Adequate Intake; ALA: alpha-linolenic acid; ARP: antiradical power; DHA: docosahexaenoic acid; DPPH$^\bullet$: 2,2-diphenyl-1-picrylhydrazyl; FRAP: ferric-reducing ability of plasma; LA: linoleic acid; LDL: low density lipoprotein; EPA: eicosapentaenoic acid; ORAC: oxygen radical absorbance assay; PUFA: polyunsaturated fatty acids.

INTRODUCTION

In nutritional terms, human physiology evolved in the context of wild plants and animals in the wild. Most likely, human beings made use of both aquatic and terrestrial foods. Over the past 20 years, many studies and clinical investigations have been carried out on the metabolism of polyunsaturated fatty acids (PUFAs) in general and on omega-3 fatty acids in particular. Today we know that omega-3 fatty acids are essential for normal growth and development and may play an important role in the prevention and treatment of coronary artery disease, hypertension, diabetes, arthritis, other inflammatory and autoimmune disorders, and cancer (1-10). Research has been carried out in animal models, tissue cultures, and human beings. The original observational studies have given way to controlled clinical trials. Great progress has taken place in our knowledge of the physiologic and molecular mechanisms of the various fatty acids in health and disease. Specifically, their beneficial effects have been

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shown in the prevention and management of coronary heart disease (11-14), hypertension (15-17), type 2 diabetes (18,19), renal disease (20, 21), rheumatoid arthritis (22), ulcerative colitis (23), Crohn's disease (24), and chronic obstructive pulmonary disease (25). Epidemiologic studies indicate that fruits and vegetables decrease the risk of chronic diseases, including cancer, cardiovascular and cerebrovascular disease. This protection has been attributed to the various antioxidants contained in them (26-29).

Oxidative damage, as a result of normal metabolism or secondary to environmental pollutants, leads to free radical formation which has been considered to play a central role in cancer and atherosclerosis. Therefore, antioxidants, which can neutralize free radicals, may be important in the prevention of these diseases. However, results from intervention trials with single compounds such as vitamins E and C or beta-carotene have not supported any protective effect (30-36). In fact, supplementation with beta-carotene resulted in adverse disease outcomes in clinical trials (37-40). One reason for the ineffective clinical trials may be the fact that the protective effects of fruits and vegetables most likely result from the action of lesser known antioxidant compounds, or from a mixture of antioxidants present in foods. Thus, a number of dietary antioxidants, such as flavonoids, carotenoids, polyphenols and sulfides, etc., are bioactive and work synergistically as do vitamin C and vitamin E. This hypothesis led to the thinking that the total amount of electron-donating antioxidants in the diet, derived from a combination of various antioxidants occurring naturally in foods, need to be determined. A number of methods have been used to assess the total antioxidant capacity of dietary plants (41-43). This paper focuses on omega-3 fatty acids and antioxidants in edible wild plants.

EVOLUTIONARY ASPECTS OF DIET

On the basis of estimates from studies in Paleolithic nutrition and modern-day hunter-gatherer populations, it appears that human beings evolved consuming a diet that was much lower in saturated fatty acids than is today's diet (44). Furthermore, the diet contained small and roughly equal amounts of omega-6 and omega-3 PUFAs (ratio of 1-2:1) and much lower amounts of *trans* fatty acids than does today's diet (Fig. 1) (45, 46). Wild plants contributed higher amounts of vitamin E and vitamin C, and other antioxidants than cultivated plants, providing additional protection against cancer and atherosclerosis (7).

The current Western diet is very high in omega-6 fatty acids (the ratio of omega-6 to omega-3 fatty acids is 10 - 20:1) because of the indiscriminate recommendation to substitute omega-6 fatty acids for saturated fats to lower serum cholesterol concentrations (48). Table I compares the omega-6: omega-3 intake of various populations (49-53). The population of Crete obtained a higher intake of alpha-linolenic acid (ALA) from purslane and other wild plants, walnuts and figs, whereas the Japanese obtained it from canola oil and soybean oil (49).

Intake of omega-3 fatty acids is much lower today because of the decrease in fish consumption and the industrial production of animal feeds rich in grains containing omega-6 fatty acids, leading to production of meat rich in omega-6 and poor in omega-3 fatty acids (54). The same is true for cultured fish (55) and eggs (56). Even cultivated vegetables contain fewer omega-3 fatty acids than do plants in the wild (57, 58). In summary, modern agriculture, with its emphasis on production, has decreased the omega-3 fatty acid content in many foods: green leafy vegetables, animal meats, eggs, and even fish. Although RDAs do not officially exist, the Adequate Intake (AI) of essential fatty acids has been established (59) as well as the ratio of $18:2\omega6$ to $18:3\omega3$ (60).

EFFECTS OF DIETARY ALA COMPARED WITH LONG-CHAIN OMEGA-3 FATTY ACID DERIVATIVES ON PHYSIOLOGIC INDEXES

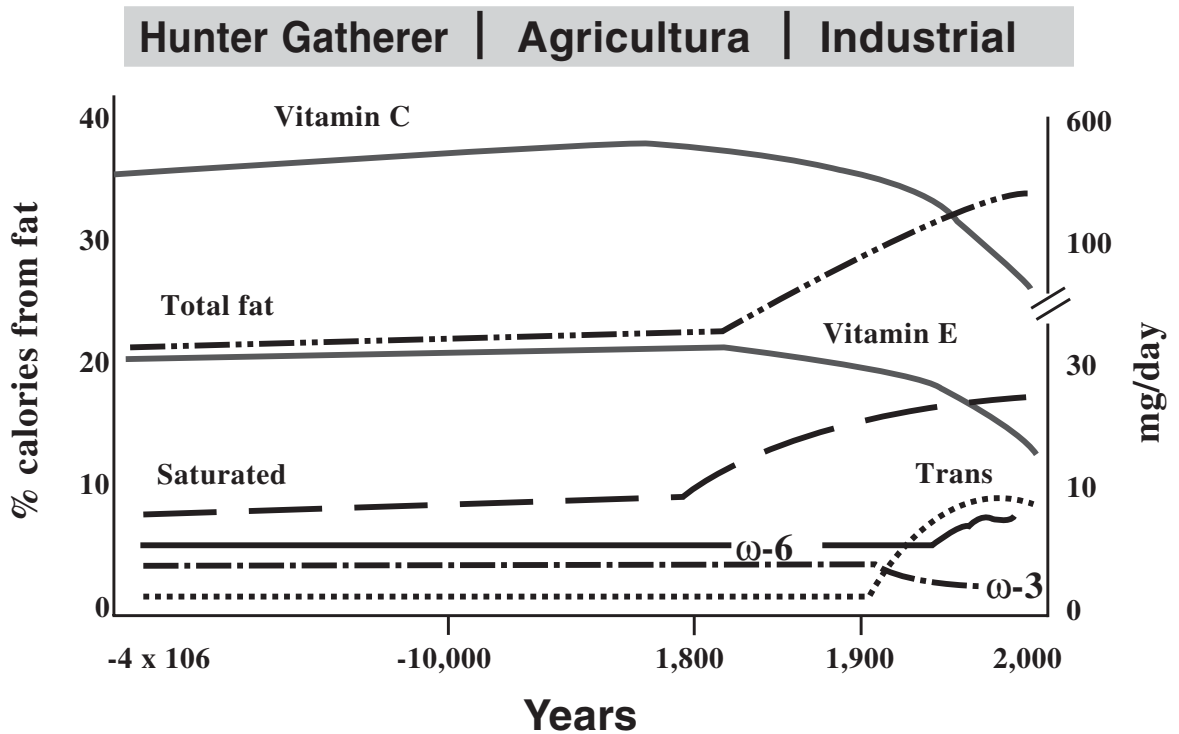Several clinical and epidemiologic studies have been conducted to determine the effects

Hunter Gatherer │ Agricultura │ Industrial

Figure 1. Hypothetical scheme of fat, fatty acid (ω-6, ω-3, trans and total) intake (as percent of calories from fat) and intake of vitamins E and C (mg/d).

Data were extrapolated from cross-sectional analyses of contemporary hunter-gatherer populations and from longitudinal observations and their putative changes during the preceding 100 years. Trans fatty acids, the result of the hydrogenation process, have increased dramatically in the food supply during this century (46).

TABLE I

Omega-6:omega-3 ratios in various populations

Population	omega-6:omega-3	Reference
Paleolithic	0.79	50
Greece prior to 1960	1.00 – 2.0	51
Current US	16.74	50
Current UK and Northern Europe	15.00	52
Current Japan	4.00	53

of long-chain omega-3 PUFAs on various physiologic indexes (7). Whereas the earlier studies were conducted with large doses of fish or fish-oil concentrates, more recent studies have used lower doses (14). ALA, the precursor of omega-3 fatty acids, can be converted to long-chain omega-3 PUFAs and can therefore be substituted for fish oils. The minimum intake of long-chain omega-3 PUFAs needed for beneficial effects depends on the intake of other fatty acids. Dietary amounts of linoleic acid (LA) as well as the ratio of LA to ALA appear to be important for the metabolism of ALA to long-chain omega-3 PUFAs. Indu and Ghafoorunissa (61) showed that while keeping the amount of dietary LA constant, 3.7 g ALA appears to have biological effects similar to those of 0.3 g long-chain omega-3 PUFA with conversion of 11 g ALA to 1 g long-chain omega-3 PUFA. Thus, a ratio of 4 (15 g LA: 3.7 g ALA) is appropriate for conversion. This ratio is also consistent with the Lyon Heart Study (12). In human studies, Emken et al. (62) showed that the conversion of deuterated ALA to longer-chain metabolites was reduced by ~50 % when dietary intake of LA was increased from 4.7 % to 9.3 % of energy as a result of the known competition between omega-6 and omega-3 fatty acids for desaturation.

Indu and Ghafoorunissa (61) further indicated that increasing dietary ALA increases eicosapentaenoic acid (EPA) concentrations in plasma phospholipids after both 3 and 6 wk of intervention. Dihomo-γ-linolenic acid ($20:3\omega6$) concentrations were reduced but arachidonic acid (AA) concentrations were not altered. The reduction in the ratio of long-chain omega-6 PUFAs to long-chain omega-3 PUFAs was greater after 6 wk than after 3 wk. Indu and Ghafoorunissa were able to show antithrombotic effects by reducing the ratio of omega-6 to omega-3 fatty acids with ALA-rich vegetable oil. After ALA supplementation there was an increase in long-chain omega-3 PUFA in plasma and platelet phospholipids and a decrease in platelet aggregation. ALA supplementation did not alter triacylglycerol concentrations. As shown by others, only omega-3 long-chain PUFAs have triacylglycerol-lowering effects (63).

In Australian studies, ventricular fibrillation in rats was reduced with canola oil as much or even more efficiently than with fish oil, an effect attributable to ALA (64). Further studies should be able to show whether this result is a direct effect of ALA per se or occurs as a result of its desaturation and elongation to EPA and docosahexaenoic acid (DHA).

The diets of Western countries have contained increasingly larger amounts of LA, whish has been promoted for its cholesterol-lowering effect. It is now recognized that dietary LA favors oxidative modification of LDL cholesterol (65, 66), and increases platelet response to aggregation (67). In contrast, ALA intake is associated with inhibitory effects on the clotting activity of platelets, on their response to thrombin (68, 69), and on the regulation of AA metabolism (70). In clinical studies, ALA contributed to lowering of blood pressure (71). In a prospective epidemiological study, Ascherio et al. (72) showed that ALA is inversely related to the risk of coronary heart disease in men.

ALA is not equivalent in its biological effects to the long-chain omega-3 fatty acids found in marine oils. EPA and DHA are more rapidly incorporated into plasma and membrane lipids and produce more rapid effects than does ALA. Relatively large reserves of LA in body fat, as are found in vegans or in the diet of omnivores in Western societies, would tend to slow down the formation of long-chain omega-3 fatty acids from ALA. Therefore, the role of ALA in human nutrition becomes important in terms of long-term dietary intake. One advantage of the consumption of ALA over omega-3 fatty acids from fish is that the problem of insufficient vitamin E intake does not exist with high intake of ALA from plant sources.

EDIBLE WILD PLANTS AS A SOURCE OF ALPHA-LINOLENIC ACID

In view of the fact that a number of studies indicate that $18:3\omega3$ (ALA) is converted to EPA and DHA in human beings, it is

important to consider terrestrial sources of omega-3 fatty acids in the food supply. ALA, the precursor to EPA and DHA, was first isolated from hempseed oil in 1887 (73). In plants, leaf lipids usually contain large proportions of 18:3ω3, which is an important component of chloroplast membrane polar lipids. Mammals who feed on these plants convert 18:3ω3 to EPA and DHA, the long-chain omega-3 fatty acids found in fish.

Wild animals and birds who feed on wild plants are very lean with a carcass fat content of only 3.9 % (74) and contain about five times more polyunsaturated fat per gram than is found in domestic livestock (54,75). Most importantly, 4 % of the fat of wild animals contains EPA whereas domestic beef contains very small or undetectable amounts, since cattle are fed grains that are rich in omega-6 fatty acids and poor in omega-3 fatty acids (76), whereas a deer that forages on ferns and mosses contains omega-3 fatty acids in its meat.

Lipids of liverworts, ferns, mosses and algae include 16:4ω3, 18:3ω3, 20:5ω3 and 22:6ω3. These are of particular interest because, unlike the higher plants in which 18:3ω3 and 16:3ω3 are the more abundant, they contain long-chain omega-3 fatty acids such as 20:5ω3 (liverwort = 9-11 %) depending on their state of development. Mosses growing in or near water contain higher percentages of C20 and C22 PUFAs and are morphologically simpler than those that live in dry habitats (77). Thus both the plants, and the animals that feed on them, are good sources of omega-3 fatty acids for human consumption.

In 1984, we initiated a series of studies of the omega-3 fatty acid and antioxidant content of purslane (*Portulaca oleracea*) and other edible wild plants and compared them to cultivated plants (47,57,58,78-83).

Purslane is one of the plants that was part of the diet of hunter-gatherers in the Pacific Northwest section of the U.S. The large native population encountered at contact (ca. 1790-1850) was non-agricultural and obtained their food by foraging, harvesting and sometimes managing, natural, localized species of plants and animals. In a recent study, Norton et al. studied the vegetable food products of the foraging economies of the Pacific Northwest and found them to be valuable sources of calcium, magnesium, iron, zinc and ascorbic acid (84). Norton states, "These members of the Lily, Purslane, Barberry, Currant, Rose, Parsley, Heath, Honeysuckle, Sunflower and Water-Plantain families are among those regularly collected by these foraging groups whose economic strategies were keyed to the use of multiple resources and the storage of large quantities of processed foods. Stored vegetable foods along with dried fish provide ample and nutritious diets during the seasonal periods of resource non-productivity. Analyses show that these native foods are superior to cultigens in necessary fiber, minerals and vitamins making substantial contributions to pre-contact diets." The results of this study revealed that a wide variety of foods were used to meet nutritional needs and that native preparation and preservation techniques were important factors in retaining nutrients, and in maintaining a balanced diet during seasons of low productivity. The study indicates that vegetable foods were systematically gathered and processed in quantity.

The wide variety of vegetables eaten along the Mediterranean and by foragers contrasts with the relatively narrow variety of crops produced by horticulturists and traditional agriculturists today. Purslane is the eighth most commonly distributed plant in the world. It is eaten both fresh and dry in many parts of the world, including Crete. Table II includes the amount of omega-3 fatty acids in milligrams per gram wet weight of purslane and other commonly eaten leafy vegetables (spinach, buttercrunch lettuce, red leaf lettuce, and mustard greens). As indicated in Table II, purslane contains 8.5 mg of fatty acids per gram of wet weight. In contrast, the other plants are relatively low in lipid content: spinach contains 1.7 mg/g, mustard greens 1.1 mg/g, red leaf lettuce 0.7 mg/g, and buttercrunch lettuce 0.6 mg/g. Purslane, with 4 mg of 18:3ω3/g wet weight, is a

TABLE II

Fatty acid content of plants (mg/g of wet weight)

Fatty acid	Purslane	Spinach	Buttercrunch Lettuce	Red Leaf Lettuce	Mustard
14:0	0.16	0.03	0.01	0.03	0.02
16:0	0.81	0.16	0.07	0.10	0.13
18:0	0.20	0.01	0.02	0.01	0.02
18:1ω9	0.43	0.04	0.03	0.01	0.01
18:2ω6	0.89	0.14	0.10	0.12	0.12
18:3ω3	4.05	0.89	0.26	0.31	0.48
20:5ω3	0.01	0.00	0.00	0.00	0.00
22:6ω3	0.00	0.00	0.001	0.002	0.001
Other	1.95	0.43	0.11	0.12	0.32
Total Fatty Acid Content	8.50	1.70	0.601	0.702	1.101

Modified from reference 57.

good nonaquatic source of 18:3ω3. Based on the information available from the provisional USDA table (85) and our studies (57, 58), purslane, a wild growing plant, is the richest source of omega-3 fatty acids of any green leafy vegetable yet examined.

EDIGLE WILD PLANTS AS A SOURCE OF ANTIOXIDANTS

Consumption of fruits and vegetables has been associated with protection against various diseases, including cardiovascular, cerebro-vascular disease and cancer (26-29). It is not known for certain what active dietary constituents contribute to the beneficial effects, but it is often assumed that antioxidant nutrients contribute to this defense. Results from intervention trials on the protective effect of the supplementation with antioxidants such as beta-carotene and vitamin E are not conclusive (39). Therefore, the beneficial effect of a high intake of fruits and vegetables on the risk of cardiovascular disease and cancer may rely not on the effect of the well characterized antioxidants, such as vitamin E and C and beta-carotene, but rather on some other antioxidants or non-antioxidant phytochemicals or by an additive action of different compounds present in foods such as alpha-linolenic acid, various phenolic compounds and fiber.

Wild plants are typically known to have higher levels of vitamin C than cultivated ones (44). Studies from Paleolithic nutrition indicate that the amount of vitamin C obtained by humans from eating a variety of wild plants was much higher, about 390 mg/day versus the 88 mg average intake obtained today in the US (44).

We have determined levels of endogenous antioxidants (alpha-tocopherol, ascorbic acid, beta-carotene and glutathione) in plant leaves sampled simultaneously for lipids as previously reported (79). Table III shows the content of alpha-tocopherol, ascorbic acid and beta-carotene in chamber-grown purslane, wild purslane and spinach expressed in mg/100 g fresh weight and in mg/100 g dry weight. The studies were expanded to include 25 commonly eaten wild plants in Crete. In addition to the vitamin E, total phenols and total antioxidant capacity were determined (81).

Alpha-Tocopherol and Ascorbic Acid

In a previous survey of the antioxidant content of nine different weed species, it was recorded that levels of alpha-tocopherol ranged from 10 to 83 mg, and levels of ascorbic acid ranged from 2 to 861 mg/100 g dry weight (Table IV) (86).

TABLE III

Antioxidant content of purslane and spinach leaves

	Alpha-Tocopherol	Ascorbic Acid	Beta-Carotene
Content, mg/100 g fresh weight			
Chamber-grown purslane	12.2 ± 0.4	26.6 ± 0.8	1.9 ± 0.08
Wild purslane	8.2 ± 0.3	23.0 ± 0.6	2.2 ± 0.1
Spinach	1.8 ± 0.09	21.7 ± 0.5	3.3 ± 0.5
Content, mg/100 g dry weight			
Chamber-grown purslane	230 ± 9	506 ± 17	38.2 ± 2.4
Wild purslane	170 ± 8	451 ± 14	43.5 ± 3.0
Spinach	36 ± 4	430 ± 15	63.5 ± 5.7

Data represent mean value from four analyses each with three replicates per species/type.
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TABLE IV

Antioxidant content of different plant species[1]

Plant species	Antioxidants, mg/100 g dry weight	
	Ascorbic acid	Alpha-tocopherol
Morning glory	2 ± 1	10 ± 3
Lamb's quarter	58 ± 18	12 ± 3
Alfalfa	143 ± 12	10 ± 1
Pigweed	504 ± 24	10 ± 1
Buckwheat	537 ± 27	28 ± 2
Mustard	469 ± 24	50 ± 9
Sicklepod	861 ± 73	60 ± 6
Velvetleaf	92 ± 7	50 ± 4
Jimson weed	114 ± 29	83 ± 16

[1] Values given for the antioxidants represent the mean ± SE of 6 plants of each species. Adapted from Table I in reference 86.

Relative to these findings, and other reports, levels of alpha-tocopherol found in purslane, 230 ± 9 mg/100 g dry weight, are up to 10 times higher than has been recorded in other weeds (Tables III and IV) (9). Alpha-tocopherol was present in spinach leaves at a level of 30-40 mg/100 g dry weight (Table III). The ascorbic acid content of chamber-grown purslane fell within the range previously reported for other weed species (Table IV) (86), but was significantly higher (506 ± 17 mg/100 g dry weight) than the level found in spinach leaves (430 ± 5 mg/100 g dry weight) (Table III).

Beta-Carotene

In photosynthetic tissues of higher plants, beta-carotene and other carotenoids are localized in chloroplasts; while there is little qualitative difference in the pigments present, there is considerable quantitative variation between different species (87, 88). The levels of beta-carotene were not significantly different in leaves of chamber-grown (38.2 ± 2.4 mg/100 g dry weight) compared to wild purslane (43.5 ± 3.0 mg/ 100 g dry weight), but these levels were lower than those present in spinach (63.5 ± 5.7 mg/100 g dry weight) (Table III).

Glutathione

The protective role of glutathione as an antioxidant and detoxifying agent has been demonstrated in various clinical studies. It is a ubiquitous compound that is synthesized rapidly in the liver, kidney, and other tissues, including the gastrointestinal tract. In animal cells, glutathione acts as a substrate for glutathione peroxidase, which reduces lipid peroxides that are formed from polyunsaturated fatty acids (PUFA) in the diet, and as a substrate for glutathione-S transferase, which conjugates electrophilic compounds. Recent studies show that glutathione obtained from the diet is directly absorbed by the gastrointestinal tract and thus dietary glutathione can readily increase the antioxidant status in humans (89). Dietary glutathione, in addition to levels supplied by the bile, may be used by the small intestine to decrease the absorption of peroxides. These results indicate that in the intact animal, luminal glutathione is available for use by the intestinal epithelium to metabolize peroxides and other reactive species and to prevent their transport to other tissue.

Dietary glutathione occurs in highest amounts in fresh meats, in moderate amounts in some fruits and vegetables, whereas it is absent or found only in small amounts in grains and dairy products (90). Only fresh asparagus at 28.3 mg/100 g and fresh avocado at 27.7 mg/100 g were higher than purslane in glutathione content in a study carried out to determine the glutathione content of 98 food items, identified by the National Cancer Institute, to contribute 90 % or more of calories, dietary fiber, and 18 major nutrients in the US diet (90-92).

The potential health effects of dietary intake of glutathione in humans are shown in Table V (89,93-101). In a recent study by Flagg et al. (102), plasma glutathione concentrations varied widely in humans and were influenced by sex and age (increased with age in men, but decreased with age and were lower in women who used estrogen-containing contraceptives).

Glutathione is now known to be widely distributed in plant cells and is the major free thiol in many higher plants (103-106). Considerable variations in levels of glutathione have been reported by different studies recording thiol levels in a variety of plant species. This may be partially due to the use of different analytical techniques, and because glutathione levels vary both diurnally (107,108) and with developmental and environmental factors (109-111). Taking into account these considerations, the levels of glutathione found in purslane, 14.81 ± 0.78 mg/100 g fresh weight, were in the range of those reported for other plant species but significantly higher than the level of 9.65 ± 0.62 mg/100 g fresh

TABLE V

Potential health effects of dietary glutathione in humans

Glutathione may protect cells from carcinogenic processes through a number of mechanisms:

1. By functioning as an antioxidant [89,93].
2. By binding with mutagenic chemical compounds [94,95].
3. By directly or indirectly acting to maintain functional levels of other antioxidants such as vitamins C and E and beta-carotene [95-97].
4. Through its involvement in the DNA synthesis and repair [98,99].
5. By enhancing the immune response [100,101].

Adapted from Jones et al. [90].

weight for spinach (Table VI). Glutathione was present in significantly greater amounts in chamber-grown purslane relative to wild plants, which may have reflected a difference in the developmental stage of the plants analyzed, or in the environmental conditions experienced.

Additional studies were carried out on 25 most commonly eaten wild plants in the Island of Crete (81). Table VII contains the scientific names and the uses of the wild plants of Crete. Table VIII shows the alpha-tocopherol and the total phenols content. Finally, Table IX shows the antioxidant activity and antiradical power of the wild plants (81).

TABLE VI

Glutathione content of purslane and spinach leaves

	GSH	GSSX	GSH/GSSX
Chamber-grown purslane	14.81 ± 0.78 (0.48)	2.20 ± 0.15 (0.031)	6.73
Wild purslane	11.90 ± 0.63 (0.39)	1.42 ± 0.12 (0.023)	8.38
Spinach	9.65 ± 0.62 (0.31)	2.39 ± 0.20 (0.039)	4.03

Data represent mean values (mg/100 g fresh weight) from four analyses each with three replicates per plant species/type. Figures in parentheses are values expressed as µmol/g fresh weight to allow comparison with data previously reported in the literature. GSH = glutathione; GSSX = glutathione-linked disulfides. Reproduced with permission from reference 58.

TABLE VII

The scientific names and the uses of the Cretan wild plants

Nº	PLANTS NAMES	USES
1	*Papaver rhoeas*	Cooked with olive oil, vegetable pie
2	*Sonchus Oleraceus*	Boiled salad, Cooked with olive oil, vegetable pie, raw salad
3	*Pimpinela peregrina*	Cooked with oil, vegetable pie
4	*Centaurea idaea*	Boiled salad
5	*Tragopogon Sinuatus*	Cooked with olive oil, vegetable pie
6	*Crepis Commutata*	Boiled salad
7	*Helmintotheca echioides*	Boiled salad
8	*Tordylium apulum*	Cooked with oil, vegetable pie
9	*Scandix pecten-veneris*	Cooked with olive oil, vegetable pie
10	*Pontikes*	Cooked with olive oil, vegetable pie, raw salad
11	*Allium subhirstum*	Cooked with olive oil, vegetable pie
12	*Rumex ssp.*	Cooked with olive oil, vegetable pie
13	*Silene Vulgaris*	Cooked with olive oil, vegetable pie
14	*Crepis vesicaria*	Boiled salad
15	*Uropermun picroides*	Boiled salad
16	*Tolpis virgata*	Cooked with olive oil, vegetable pie, Boiled salad
17	*Hypochoeris radicata*	Boiled salad
18	*Cichorium pumilum*	Boiled salad
19	*Oebothera pimpineloides*	Cooked with olive oil, vegetable pie
20	*Leontodon tuberosus*	Cooked with olive oil, vegetable pie
21	*Cichorium spinosum*	Boiled salad, raw salad
22	*Ranunculus ficarioides*	Cooked with olive oil, vegetable pie, Boiled salad, raw salad
23	*Prasium majus*	Cooked with olive oil, vegetable pie
24	*Foeniculum vulgare ssp.piperitum*	Cooked with olive oil, vegetable pie
25	*Stypocaulon scoparium*	Raw salad

* Both raw and boiled salads are dressed with olive and lemon or vinegar.
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TABLE VIII

α-Tocopherol and Total Phenols content of Cretan edible wild plants

N°	Plant Names	α-tocopherol (mg/100g wet weight)	Total phenols (mg/100g wet weight)
1	*Papaver rhoeas*	0.524	33.5±0.81
2	*Sonchus oleraceus*	0.294	48.04±0.79
3	*Pimpinela peregrina*	0.490	47.65±0.33
4	*Centaurea idaea*	0.108	61.55±1.45
5	*Tragopogon Sinuatus*	0.206	20.82±0.14
6	*Crepis Commutata*	0.360	49.08±2.32
7	*Helmintotheca echioides*	0.029	44.86±1.08
8	*Tordylium apulum*	2.426	46.87±1.25
9	*Scandix pecten-veneris*	1.133	46.51±1.13
10	*Pontikes*	0.360	59.27±1.10
11	*Allium subhirstum*	1.215	14.54±0.65
12	*Rumex ssp.*	0.509	102.56±3.13
13	*Silene Vulgaris*	0.354	40.18±1.20
14	*Crepis vesicaria*	0.401	49.42±2.87
15	*Uropermum picroides*	0.482	35.76±0.54
16	*Tolpis virgata*	0.043	21.46±0.47
17	*Hypochoeris radicata*	0.193	57.03±0.32
18	*Cichorium pumilum*	0.420	93.64±0.28
19	*Oenothera pimpineloides*	0.232	55.05±1.31
20	*Leontodon tuberosus*	0.099	48.06±0.39
21	*Cichorium spinosum*	0.398	72.63±0.37
22	*Ranunculus ficarioides*	0.443	32.99±0.60
23	*Prasium majus*	1.287	78.72±0.44
24	*Foeniculum vulgare ssp.piperitum*	1.117	82.521±0.60
25	*Stypocaulon scoparium*	0.000	6.736±0.52

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TABLE IX

Antioxidant Activity and Antiradical Power of Cretan edible wild plants.

N°	Plant Names	Antioxidant Activity(EC50) (mg dry extract/mg DPPH)	ARP (1/EC50)
1	*Papaver rhoeas*	0,995±0.14	1,005±0.15
2	*Sonchus oleraceus*	3,664±0.05	0,273±0.004
3	*Pimpinela peregrina*	2,909±0.29	0,346±0.036
4	*Centaurea idaea*	1,400±0.011	0,714±0.005
5	*Tragopogon Sinuatus*	3,679±0.16	0,272±0.012
6	*Crepis Commutata*	3,169±0.14	0,316±0.014
7	*Helmintotheca echioides*	2,344±0.17	0,428±0.031
8	*Tordylium apulum*	2,852±0.13	0,351±0.017
9	*Scandix pecten-veneris*	2,477±0.11	0,404±0.018
10	*Pontikes*	7,261±0.25	0,138±0.005
11	*Allium subhirstum*	2,697±0.08	0,371±0.01
12	*Rumex ssp.*	2,344±0.17	0,428±0.03
13	*Silene Vulgaris*	2,852±0.13	0,351±0.02
14	*Crepis vesicaria*	2,284±0.42	0,438±0.09
15	*Uropermum picroides*	0,830±0.20	1,205±0.37
16	*Tolpis virgata*	1,350±0.12	0,741±0.06
17	*Hypochoeris radicata*	0,761±0.22	1,390±0.45
18	*Cichorium pumilum*	0,696±0.55	2,039±1.18
19	*Oenothera pimpineloides*	0,222±0.018	4,520±0.35
20	*Leontodon tuberosus*	1,194±0.047	0,838±0.03
21	*Cichorium spinosum*	1,115±0.28	0,944±0.28
22	*Ranunculus ficarioides*	0,280±0.08	3,812±1.27
23	*Prasium majus*	0,818±0.27	1,321±0.46
24	*Foeniculum vulgare ssp.piperitum*	1,041±0.15	0,974±0.14
25	*Stypocaulon scoparium*	2,367±0.19	0,424±0.035

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Phenols

Flavonoids and other phenolic compounds are antioxidants that contribute to the high antioxidant capacity observed in certain fruits and vegetables. There are several thousand different flavonoids present in plants, and many of them have antioxidant activities (112). The antioxidant capacities, measured as oxygen radical absorbance assay (ORAC) of some flavonoids were found to be several times stronger on the basis of molar concentration than vitamins E and C (112). Such phenolic compounds have already been implicated as playing a role in the protection that fruits and vegetables have against chronic diseases (112). However, the extent to which these potentially important antioxidants can be absorbed is not clear, although early evidence indicates that substantial quantities of the flavonoids are absorbed.

Antioxidant Capacity

Various methods have been developed to measure total antioxidant capacity or activity, such as the ORAC (43), or the 2,2-diphenyl-1-picrylhydrazyl (DPPH•) (113) free radical assay which measures the antiradical power (ARP): the higher the ARP, the more efficient the antioxidant. In general, more than 80 % of the total antioxidant capacity in fruits and vegetables comes from ingredients other than vitamin C, indicating the presence of other potentially important antioxidants in these foods (43). ORAC varies considerably (20-30 fold) from one kind of fruit or vegetable to another. As expected, the majority of studies have been carried out in cultivated fruits and vegetables. Brussel sprouts are one of the vegetables that show high ORAC activity. Garlic, kale, and spinach are particularly high, as are strawberries and plums.

In a recent paper on the systematic screening of total antioxidants in dietary plants, using the ferric-reducing ability of plasma (FRAP) method (43), Halvorsen et al. (114) emphasized the need for a systematic analysis in order to facilitate research into the nutritional role of a combined effect of antioxidants in dietary plants.

CONCLUSIONS

Current research clearly shows that human beings evolved on a diet that was based on wild plants, particularly green leafy vegetables, meat from animals in the wild, and fish from rivers, lakes and deep cold sea water. This diet provided equal amounts of omega-6 and omega-3 essential fatty acids. Furthermore, the diet contained omega-3 fatty acids from terrestrial sources (predominately ALA) and high amounts of EPA and DHA from both animals and fish. The green leafy vegetables provided antioxidant vitamins, minerals, and various phytochemicals with antioxidant properties.

Studies on wild plants relative to the omega-3 fatty acids and antioxidant content are being carried out in various parts of the world. As expected, they show enormous variation in the content of both omega-3 fatty acids and antioxidants due to variation in climatic conditions and cultivars. In developing new sources of food, the study of the dietary composition of wild plants is essential. Their cultivation should lead to increased production of plants rich in omega-3 fatty acids and antioxidants, both of which reduce the risk of chronic diseases.

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