*Review Paper:*

# A review of the antioxidant activity of *Apium Graveolens*

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***Abstract***
*Plants are an important source of natural active products that differ depending on the chemical components they contain. Since extracts and phytochemicals isolated from plants show biological activity in vitro and in vivo, today plants are used as alternative treatment sources.*

*Apium graveolens (celery) has powerful antioxidant properties to remove free radicals due to compounds such as coumarin, alkaloids, steroids, phenols, essential oils, sesquiterpene alcohols, caffeic acid, p-coumaric acid, ferulic acid, apigenin, luteolin, tannin, saponin and kaempferol. Celery with different compounds and different concentrations has various healing effects. The aim of this study was to review the antioxidant activity of celery.*

**Keywords**: *Apium graveolens L,* celery, antioxidant activity.

## Introduction

The use of medicinal plants to treat illness has been common since ancient times. Many studies have shown the positive effects of various herbs and different parts of medicinal plants on cancer, infectious diseases, diabetes, atherosclerosis.[30,37,39] Phenolic and alkaloid compounds in plants and their effects such as antioxidant effects have been investigated in many studies such as cancer,[2,18,41] diabetes,[16,23] liver disorders,[30] coronary heart diseases etc.[24,25] Today herbal drugs are used as an alternative to chemical drugs due to their low side effects.

Celery (*Apium graveolens* L) is a plant from the apiaceae family and is one of the annual or perennial plants that grow throughout Europe, Africa and Asia[15]. Celery seeds are used as a condiment in the flavoring of food products possessing a characteristic aroma and pungent taste. There are a number of phthalide derivatives that give the celery essential oil a characteristic odor.[19]

Celery (*Apium graveolens*) is a medicinal plant in traditional medicine with numerous health benefits. Celery can prevent arthritis, rheumatism, gout, urinary tract inflammation and specifically rheumatoid arthritis with mental depression.[5] Celery, because of compounds such as caffeic acid, p-coumaric acid, ferulic acid, apigenin, luteolin, tannin, saponin and kaempferol, has powerful antioxidant characteristics to remove free radicals. Antioxidants with radical scavenging capacity are thought to have a potential protective effect against free radical damage. These biomolecules inhibit oxidative reactions that prevent the formation of coronary and vascular diseases and tumors.[19,26]

This oxidative damage is the result of free radical action on, for instance, lipids or DNA. However, the commonly used synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxyl toluene (BHT), are limited by law because of their toxic effects and carcinogenicity.[28] The elimination of synthetic antioxidants in food applications has provided further impetus to explore the source of natural antioxidants. The objective of the present review is to highlight the antioxidant effects of *Apium graveolens.*

## Phytochemical Constituents

The preliminary phytochemical analysis revealed the presence of carbohydrates, flavonoids, alkaloids, steroids and glycosides in the methanolic extract of seeds of *Apium graveolens*[24]. Seeds included flavonoids, volatile oils, coumarins and furanocoumarins. Coumarins contained celerin, bergapten, apiumoside, apiumetin, apigravrin, osthenol, isopimpinellin, isoimperatorin, celereoside and 5 and 8-hydroxy methoxypsoralen. Flavonoid included apiin, apigenin, isoquercitrin.[5,20] The phenolic concentration in different extracts(methanol, ethanol, water) varied significantly. Among the methanol extract of the seeds, *Apium graveolens* methanolic extract had the highest phenolic concentration (73.1 ± 1.23 mg GAE/100g).[4] Volatile oils included limonene (60%) and selenine (10–15%) and various sesquiterpene alcohols (1– 3%), e.g. α-eudesmol and ß-eudesmol, santalol.

Also celery includes linoleic, myristic, myristoleic, oleic, palmitic, palmitoleic, petroselinic and stearic acid.[5] The main chemical constituents present in each part of the plant are as follows: The roots contain falcarinol, falcarindiol, panaxidol and polyacetylene 8-O-methylfalcarindiol.[1,8] The stem contains pectic polysaccharide (apiuman) containing d-galacturonic acid, 1-rhamnose, 1-arabinose and d-galactose.[34] Leaves contain 1-dodecanol, 9-octadecene-12-ynoic acid, methyl ester and tetradecene-1-ol acetate.[31] Celery seed contains caffeic acid, chlorogenic acid, apigenin, rutaretin, ocimene, bergapten and isopimpinellin.[6] The seed oil is composed of palmitic acid, stearic acid, oleic acid, linoleic acid, petroselinic acid, d-limonene, selinene, terpineol and santalol.[33]

Antioxidant Effect: In the study by Kolarovic et al,[21] the antioxidant activities[as measured by the content of reduced glutathione (GSH) and ferric reducing antioxidant power (FRAP)] of celery and parsley leaf and root juices in rats treated with doxorubicin, were investigated.

**Table 1**
**Essential oils of *A. graveolens* L. seed, GC/MS[24]**

| Celery Components | Percent (%) |
|---|---|
| D-Limonene | 57.7 |
| Myrcene | 18.7 |
| 4-Terpineol | 8.6 |
| ß-Selinene | 8.1 |
| ß-pinene | 2.4 |
| ß- caryophyllene | 0.5 |
| Carnone | 0.3 |
| Trans-Limonene Oxide | 0.3 |
| α-Terpinolene | 0.3 |
| α-selinene | 0.2 |
| Trans-3-butylidenephthalide | 0.1 |
| α-Muuroloene | 0.1 |
| Cis-Limonene Oxide | 0.1 |
| Linalool | 0.1 |
| α-pinene | 0.1 |
| Trans-ocimene | 0.1 |

Celery root juice increased antioxidative capacity and the total antioxidative capacity (TAOC) in liver homogenate. Celery leaf juice increased GSH content but did not increase FRAP in liver homogenate. Study results show that celery increases antioxidant activity.

The study by Al Sa'aidi et al[2] of antioxidant activity of n-butanol celery extract (*Apium graveolens*) seed in streptozotocin-induced diabetic rats was investigated. Thirty-two mature male rats were divided into four groups as diabetic and non-diabetic. Rats ≥ 200 mg/dl of blood glucose were used as diabetic. Diabetic groups were drenched with drinking water, n-butanol extract (60 mg/kg, b.w.), or injected with insulin (4 IU/animal) respectively for 21 days. Blood and liver subcellular fluid were obtained for the evaluation of alanine aminotransferease (ALT), Aspartate aminotransferase (AST), catalase (CAT), Superoxide dismutase (SOD), Glutathione (GSH) -transferase and -reductase enzymes and Malondialdehyde (MDA), glutathione concentrations.

N-butanol extract of celery seed or insulin therapy moderated blood glucose within a normal range, enhanced body weight gain and normalized the activities of all antioxidant enzymes. Study results show that n-butanol extract of celery seed has a potent role in ameliorating stressful complications accompanied by diabetes mellitus.

In the study by Li et al,[29] *in vitro* and *in vivo* antioxidant activity of ethanol extract of celery leaf was investigated. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) and catalase and total antioxidant capacity (TAOC) activities were measured in serum, brain, heart, liver and kidneys. As a result, celery has a radical scavenging effect and SOD, GSH-Px CAT have been shown to significantly increase the activity.

Yıldız et al[44] identified the essential antioxidant compounds and measured the total antioxidant capacity with CUPRAC (cupric ion reducing antioxidant capacity) and ABTS spectrophotometric methods. The CUPRAC spectrophotometric method of TAC assay using copper(II)-neocuproine (2,9-dimethyl-1,10- phenanthroline) was developed. Antioxidant compounds in celery plant extracted by HPLC were analyzed on one column of C18. Study results show that methanolic and ethanolic extract of celery leaves have antioxidant properties.

Yao et al[43] analyzed the phenolic compound composition and antioxidant activities of 11 celery varieties. The contents of total phenolics were measured using a Folin–Ciocalteu assay and the total antioxidant capacity was measured with the 1,1-diphenyl-2-picrylhydrazyl radical and 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) methods. The most common flavonoid in celery was apigenin and phenolic acid was p-coumaric acid.

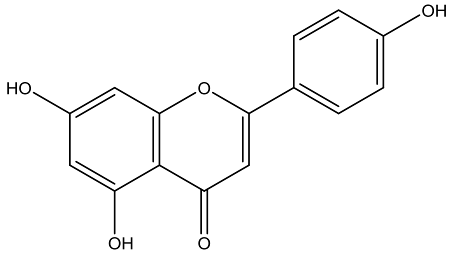
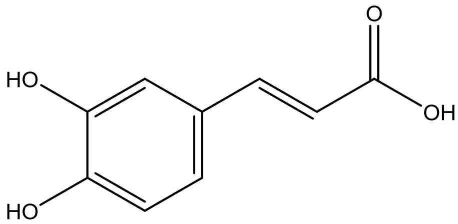
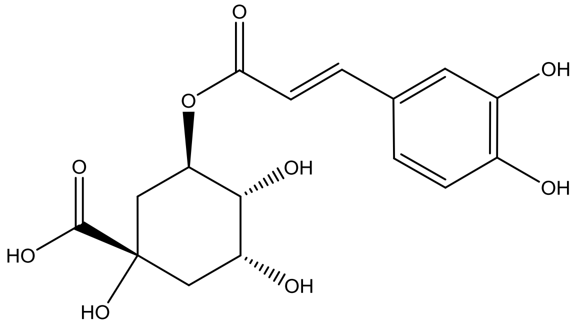
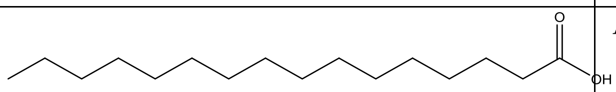
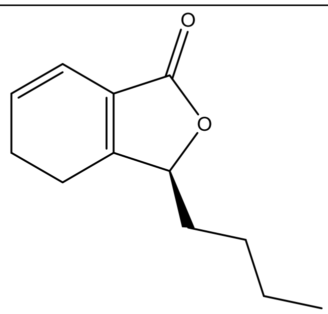
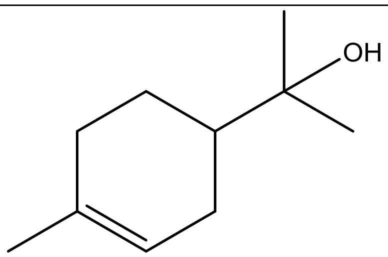
The investigated celery varieties had high levels of phenolics and exhibited high antioxidant capacity. Antioxidant activity was found to be proportional to total flavonoids, total phenolic acids or total phenolics. In the study by Nagella et al[31] essential oil composition of celery leaf, immunotoxicity effects and antioxidant activity was investigated.

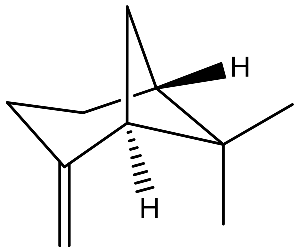
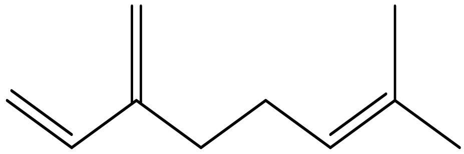
Essential oils contained in *A. graveolens* leaves were found using gas chromatography and mass spectroscopy (GC-MS). The essential oil from the *A. graveolens* leaves was investigated for scavenging of the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical activity. The results showed that the essential oil from the *A. graveolens* has potential as a natural antioxidant and thus inhibits the unwanted oxidation process.

Shanmugapriya and Ushadevi[38] studied the antibacterial and antioxidant activity of Methanol, Diethyl ether and aqueous extracts of *Apium graveolens* seeds. The antioxidant activity of *A.graveolens* seed extracts was carried out 2, 2-Diphenyl-1- picrylhydrazyl (DPPH) assay method. The methanol extract showed the highest inhibition against bacterial pathogens and higher antioxidant activity than that of standard Gallic acid. Study result showed that *A. graveolens* seed extract is exhibiting enormous significance in therapeutic aspects. Uddin et al evaluated the phytochemical screenings, antioxidant activity and antimicrobial assay of *Apium graveolens* L.

The total phenolic content was slightly higher in methanolic fraction (63.46 ± 12.00 mg GAE/g) than ethanol (36.60 ± 12.28 mg GAE/g) and hexane fractions (34.86 ± 6.96 mg GAE/g). The flavonoid content was high in methanolic extract (56.95 ± 7.14 mg Quercetin/g). Ethanol extract showed good antimicrobial activity. Antioxidant activities of extracts were measured according to DPPH, ABTS and FRAP assays.

**Table 2**
**The chemical constituent of the *Apium graveolens* L seed**

| Group of Chemicals | Chemical Constituents | Structure | Reported Activity |
|---|---|---|---|
| Glycosides | Apigenin |  apigenin | Antioxidant[7,29] |
| Organic acid | Caffeic acid |  caffeic acid | Antioxidant[10] |
| Organic acid ester | Chlorogenic acid |  Chlorogenic acid | Antioxidant[36] |
| Fatty acids | Palmitic acid |  Palmitic acid | Antioxidant[14,40] |
| Essential Oil | Sedanolide |  sedanenolide | Antioxidant[42] |
| Essential Oil | Terpineol (2-(4-Methylcyclohex-3-en-1-yl)propan-2-ol) |  2-(4-Methylcyclohex-3-en-1-yl)propan-2-ol | Antioxidant[9] |

| | | | |
|---|---|---|---|
| Essential Oil | ß-pinene |  ß-pinene | Antioxidant[12] |
| Essential Oil | ß-myrcene |  ß-myrcene | Antioxidant[11] |

Antioxidant activity assayed by FRAP was higher in methanolic fraction (12.48 ± 1.06 mmole of FeSO4 equivalent/litre of extract) compared with other extracts. The study by Naglaa et al[32] for the constituents of the essential oil, antioxidant and antimicrobial activity of celery (*Apium graveolens*) was investigated. The chemical composition of the essential oils obtained by hydrodistillation was analyzed by GC/MS.

The antioxidant activities of volatile oils extracted from the celery were assessed by the Rancimat apparatus and DPPH. Study results show that all essential oils under study at various concentrations exhibited antioxidant activity.

Ksouda et al[27] investigated 25 Tunisian plant species of 13 families based on their oil and total phenolic contents. The phenolic content of seed methanolic extracts was measured by Folin–Ciocalteu assay (490 ± 60 mg GAE/100 g Dry Weight). In the ABTS assay, the antioxidant activity value was 1000 ± 150 mg TEAC/100 g DW. In the DPPH assay, the antioxidant activity value of *Apium graveolens* was 480 ± 30 (mg TEAC/100 g DW).

The results showed that the seeds of *Apium graveolens* had high oil content, interesting fatty acid profiles and its methanolic extracts displayed high antioxidant capacities.[19] The leaves of *A. graveolens* were extracted with methanol and partitioned with water, ethyl acetate and butanol.

The phenolic content of the extracts was determined by Folin-Coicalteu method. Antioxidant capacity was measured by using α, α-diphenyl-β-picrylhydrazyl (DPPH), β-carotene-linoleate, reducing power, metal chelating effects and phosphomolybdenum method. The phenolic content of the extracts was expressed as gallic acid equivalents and was found to be highest in methanol (51.09 mg/g).

At concentration of 250 g/ml, methanol extract has the highest free radical scavenging activity and reducing power. The study result showed that celery leaf vegetable is a good source of antioxidants due to its phenolic richness.

Han et al[17] investigated the effect of digestion on the phenolic compounds and antioxidant activity of celery leaf. 13 phenolic chemicals were discriminated by HPLC-MS and contents of phenolic and the antioxidant capacity were evaluated after digestion *in vitro*. The extraction of celery leaf decreased lipid peroxidation and reactive oxygen species level.

It was also found that celery leaf increased antioxidant activity of liver, spleen and thymus of mice treated with Dexamethasone. In the study by Popovic et al,[35] the potential protective action of the ether, chloroform, ethyl acetate, n-butanol and water extracts was assessed by the corresponding *in vitro* and *in vivo* tests.

In the *in vitro* experiments crude methanol extracts were tested as potential scavengers of free OH• and DPPH• radicals as well as inhibitors of liposomal peroxidation (LPx). The results showed that both the extracts of root and leaves are good scavengers of OH• and DPPH• radicals.

*In vivo* experiments were concerned with antioxidant systems (activities of GSHPx, GSHR, Px, CAT, SOD, GSH content and intensity of LPx) in liver homogenate and blood of mice after their treatment with extracts of celery leaves, or in combination with $CCl_4$. On the basis of the results obtained, n-butanol extract showed the highest protective effect.

## Conclusion

This study investigated the properties of celery leaves and seeds. Celery is a commercially important seed spice valued for its medicinal properties. Celery because of compounds such as coumarin, apigenin, luteolin, tannin, kaempferol has powerful antioxidant characteristics. The plant composition and medicinal properties need more research about its other useful and unknown properties.

**Table 3**
**Summary of Antioxidant Activity of Celery**

| Type of extract | Used Parts | Model | Results |
|---|---|---|---|
| Aqueous extract | Root and leaves[21] | *In vivo* | -Celery root juice increased antioxidative capacity, – Celery leaf juice increased GSH content |
| Aqueous extract | Seed[2] | *In vivo* | -n-Butanol extract of celery seed normalized the activities of all antioxidant enzymes |
| Ethanolic extract | Leaves[29] | *In vivo* and *in vitro* | -Scavenging activity on MDA and LPF. – Enhanced the activities of SOD, GSH-Px and CAT |
| Methanolic and Ethanolic extracts | Leaves[44] | *In vitro* | Increased total antioxidant capacity |
| Ethanolic extract | All of the parts[43] | *In vitro* | Excellent free radical scavenging activities |
| — | Leaves[32] | *In vitro* | Has potential as a natural antioxidant and thus inhibits unwanted oxidation process |
| Methanolic, diethyl ether and aqueous extracts | Seeds[38] | *In vitro* | Methanol extract showed the highest antioxidant activity |
| Methanolic, ethanol and hexane[13] extracts | — | *In vitro* | Antioxidant activity was observed |
| Aqueous extract | Seeds[32] | *In vitro* | Exhibited antioxidant activity |
| Methanolic extract | Seeds[27] | *In vitro* | Extract exhibited high antioxidant activity |
| Methanol, water, ethyl acetate and butanol extract | Leaves[19] | *In vitro* | The antioxidant and free radical scavenging activities of the extracts assayed through DPPH and reducing power were found to be highest with methanol |
| Water extract | Leaves[17] | *In vitro* and *In vivo* | The extraction of celery leaf decreased lipid peroxidation and reactive oxygen species level and elevated the antioxidant activities |
| Methanol, ethyl acetate, butanol and water extract | Root and leaves[35] | *In vitro* and *In vivo* | Root and leaves are good scavengers of OH• and DPPH• radicals and reduce liposomal peroxidation intensity in liposomes |

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