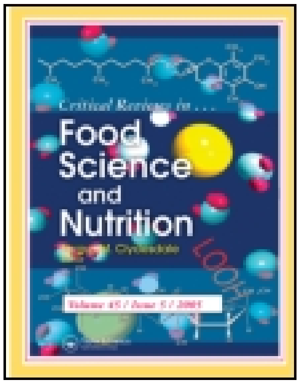

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Chemistry, Technology, and Nutraceutical Functions of Celery (Apium graveolens L.): An Overview

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Chemistry, Technology, and Nutraceutical Functions of Celery (*Apium graveolens* L.): An Overview

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Celery is a commercially important seed spice belonging to the family Umbelliferrae. *Celery is used in various forms such as fresh herb, stalk, seeds, oil, and oleoresin for flavoring of foods and for medicinal purposes. Celery seed contains 2% volatile oil that finds application for flavoring of foods and also in perfumery industry. Limonene and selinene form about 60% and 20% of the oil, respectively. However, the important flavor constituents of the oil responsible for the typical aroma are 3-*n*-butyl-4-5-dihydrophthalide (sedanenolide), 3-*n*-butyl phthalide, sedanolide, and sedanonic anhydride present in very low levels (1–3%). Celery contains 15% fatty oil with the fatty acids: petroselenic (64.3%), oleic (8.1%), linoleic (18%), linolenic (0.6%), and palmitic acids. Phthalides especially sedanenaloide possess many health benefits. Celery extracts are reported to possess many nutraceutical properties, viz., antioxidant, hypolipidemic, hypoglycemic, and anti-platelet aggregation. In the present review, the chemistry, processing, and biological activities of celery and the components responsible are discussed.*

Keywords Celery, biological activity, antioxidant, oil, oleoresin, processing, flavorant

1. INTRODUCTION

Celery (*Apium graveolens* L.), grown as a biennial or as an annual herb, is cultivated as a popular vegetable, for the green and blanched leaf stalks and to a limited extent for the edible thickened roots and crowns. Celery is a commercially important seed spice belonging to the family *Umbelliferrae*. Celery plant is indigenous to Southern Europe, Asia, and Africa. It is also found in North and South Americas. From July to November in the northern hemisphere, white to gray-white flowers appear in particulate compound umbels. Celery grows to a height of 12 to 16 inches and is composed of leaf-topped stalks arranged in a conical shape joined at a common base (Lewis, 1984). Celery seed is very small, about 1.3 mm in length, brown in color, ovoid, and ridged. The fruit is made up of two united carpels, each containing a seed. The spice has a pleasant characteristic odor and a slightly pungent taste. For flavoring foods, celery is used in various forms such as fresh herb, stalk, leaves, seeds, seed oil, and oleoresin. Celery became popular in Europe in the 18th century and in the USA it was introduced in the 19th century.

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1.1. Crop and Production

Celery is cultivated for seeds extensively in India, France, and the USA. Celery is grown annually during winter in North India either as a seed crop or as a salad crop grown on the foothills of Himalayan plains lying in Punjab and Uttar Pradesh. Celery seeds are exported to some of the continental countries like France, Italy, Netherlands, and Germany as well as to Australia and New Zealand. The plants grow well in heavily manured, sandy loam soil under mild climatic conditions. India produces 4000 tons and exports about 3000 tons per annum. In Europe, a variety that is white in color is also grown. Like white asparagus, this type of celery is grown in shade away from direct sunlight, so that production of chlorophyll, hence green color, is inhibited.

California produces about 75% of the USA's celery crop, followed by Florida and Texas. Michigan celery production yields approximately US$14,678 annually (based on a five-year average). Michigan is ranked second in the nation for celery production, with 6.3% of the national commodity. The current price of seed is Rs. 3500/ton and oil price ranges from Rs. 1500–1600/kg in India; the price of oil remains fairly stable in

Table 1 Whole celery seeds specification

Moisture (% max.)	10.0
Volatile oil (% min.)	1.5
Ash (% max.)	10.0
Acid-insoluble ash (% max.)	2.0
Average bulk index (g/100 g)	195
Mould (%) by weight	1.0
Mammalian excreta (mg/lb)	3
Other excreta (mg/lb)	3.0
Insect infested (%) by weight	1.0
Extraneous (%) by weight	0.5
Whole dead insects, by count	4

Source: IS 3797-1993.

world trade. There is a small production and market for celery resinoids also.

1.2. Composition

Celery seed contains around 8.0% moisture, 2.0% volatile oil, 15% fixed oil, 18.7% protein, 8.0% total ash, 11.0% crude fiber, 36.6% carbohydrate, and 6.0% starch (Table 1; Lewis, 1984). The fatty acids in fixed oil are made up of petroselenic (64.3%), oleic (8.1%), linoleic (18%), linolenic (0.6%), palmitic (6.9%), and stearic (1.4%) acids. Minor fatty acids are reported to be hexadecenioc (0.1%), a-linolenic (0.6%), and cis-vaccenic acids (0.5%; Destaillats and Angers, 2002). Celery is a rich source of vitamin C, potassium, calcium, and magnesium. Celery also contains high levels of sodium. A full cup of chopped celery leaves from about two stalks is known to contain approximately 100 mg of sodium.

2. PROCESSING

2.1. Freshly Harvested Celery

Seedlings are raised and transplanted to fields. Harvesting is carried out the following year. Celery leaves are used as salad, and to store celery it should be kept in a sealed container or wrapped up in a plastic bag or damped cloth and stored in the refrigerator. If peeled celery has to be stored, it should be ensured that it is dry and free from water residue, as this can drain some of its nutrients. Freezing will make celery wilt and should be avoided if it is intended to be used in a recipe involving cooking. The plants are cut, dried in the field, and threshed. The seeds are then thoroughly dried, cleaned, graded as large and small seeds, and bagged.

2.2. Celery Powder

The ground seed is mixed with salt to produce “celery salt” that is used to flavor fish, salads, and eggs. It is also used to flavor tomato juice and sauces.

2.3. Celery Essential Oil

The seeds contain 2% essential oil that is used both in flavor and fragrance industries. Celery essential oil lends a floral-like odor to oriental perfumes to which it imparts warm and clinging notes. The composition of celery volatile oil has been studied by many workers (Wilson, 1970; Gupta and Baslas, 1978; Lawerence and Reynolds, 1998) and gas chromatography-mass spectral analysis has shown that d-limonene and selinene form about 60% and 20% of the oil, respectively. However, the important flavor constituents of the oil responsible for the typical aroma are 3-*n*-butyl-4,5-dihydrophthalide (sedanenolide), 3-*n*-butyl phthalide, sedanolide, and sedanonic anhydride that are present in very low levels (Uhlig et al., 1987; Choudhary and Kaul, 1992). Seven major compounds, viz., piperitone, eugenol, ß-pinene, terpinolene 3-carene, myrcene, and menthone, have been reported in the steam-distilled celery seed oil (Guenther, 1990). Distillation of fresh celery juice and identification of flavor compounds such as phthalides and hydrophthalides have been reported (Gold and Wilson, 1963). Myrcene, limonene, butyl phthalide, pentyl benzene, and ß-caryophyllene have been reported in the oil of a selected Indian variety of celery seeds. A review on celery with composition of oil has been published (Verghese, 1990).

2.3.1. Flaking Studies

Celery seed contains higher amount of fixed oil, which cause problems during grinding operations like over-heating, clogging of mill, and loss of volatiles. As an alternative to conventional grinding, flaking of the seeds for the extraction of volatile oil and effect of flaking on the yield and physicochemical characteristics of the volatile oil has been studied (Sowbhagya et al., 2007). By flaking the celery seeds prior to steam distillation, a higher yield of volatile oil (1.76%) as against conventional powdering (1.42%) could be obtained and by precooling and flaking, yield of oil could be further improved (2.2%). Flaking did not affect the flavor profile of the oil (Fig. 1). Scanning electron microscopic studies revealed that there is a marked difference between the structures of powder and flakes (Fig. 2). In case of flakes, the cells had become ruptured and a total flattening observed that facilitated the release of higher amount of oil in a shorter duration. Lump-like structures are observed in the case of powder and the particles retain these spherical shapes and cell rupture is minimal resulting in lower yield of oil and longer time of distillation.

Selective collection of volatile oil at different intervals of time of steam distillation gives fractions of different flavor profiles. The condensate from steam distillation subjected to a second hydro distillation results in the recovery of oil (about 40–45 mL per 10 kg of celery powder) rich in phthalides and different in flavor profile from the steam-distilled seed oil.

2.3.2. Enzyme Pretreatment

Use of enzymes for flavor extraction from a few spices like fenugreek, pepper, mustard, chilli, and citrus peels has been

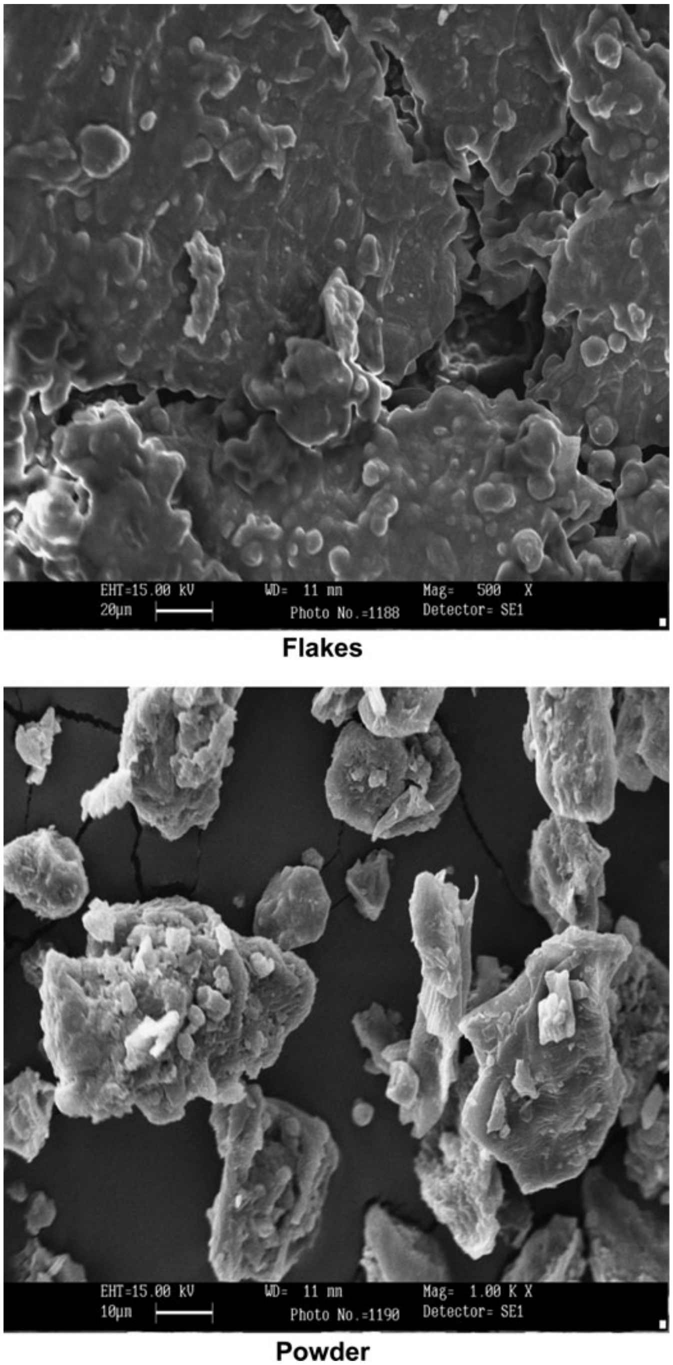

Figure 1 Scanning electron micrograph of celery flakes and powder. Adapted from Sowbhagya et al. (2007).

reported. The effect of various enzymes, viz., cellulase, pectinase, protease, and viscozyme, on the extraction of volatile oil of celery has been studied (Sowbhagya et al., 2010). The oil yield in the case of cellulase, pectinase, protease, and viscozyme pretreatment was in the range of 1.9–2.3% compared to 1.8% in the control sample by steam distillation (Table 2). A single enzyme cellulase at 0.5% resulted in a higher yield of oil, which is better than the combination of enzymes. Enzymatic pretreatment of celery seeds resulted in discernible increase in the yield of volatile oil (17–22%) in celery with little change in either flavor profile or physicochemical properties of the oil.

Table 2 Effect of enzyme pretreatment on yield of celery seed oil *(Steam distillation)

Enzymes	Enzyme concentration	Volatile oil (%)	Increase (%)
Control	Nil	1.8 ± 0.09	0
Cellulase	1.0	2.3 ± 0.08	27.7
Pectinase	1.0	2.2 ± 0.08	22.2
Protease	1.0	2.3 ± 0.08	27.7
Viscozyme	1.0	2.3 ± 0.07	27.7

Source: Adapted from Sowbhagya et al. (2010).

2.4. Celery Resin

Celery oleoresin can be obtained by two methods. (1) The coarsely ground celery powder/flakes are subjected to steam distillation to obtain the volatile oil. The powder/flakes left after volatile oil extraction is ground again to 30 mesh and extracted with solvent in percolators. The extraction is repeated five to six times with one-hour contact time with the powder each time. The extract is pooled together, which is called miscella, and subjected to distillation to remove solvent, and high vacuum is applied at the end of the distillation to remove the solvent residue. The resin obtained is mixed with the volatile oil in different proportions to obtain the oleoresin. Oleoresins extracted from old seeds may give an oxidized off-flavor. (2) Oleoresin is also prepared by solvent (hexane or acetone) extraction of celery powder without subjecting it to steam distillation followed by removal of solvent. In oleoresin prepared by this method, the finer aroma of low boiling compounds may be lost during final stages of distillation by application of high vacuum at the end of distillation to remove solvent residues to traces.

Using hexane as a solvent, both the fixed oil and essential oil is extracted from seeds that can be further fractionated with 90% alcohol that yields (1) an oleoresin containing 25% volatile oil, and (2) a fatty oil containing about 3% volatile oil. Both the products can be used for flavoring of food depending on whether the product rich in volatiles or mild-flavored product is required.

2.6. Chemistry of Celery Oil and Oleoresin

Celery seed oil is a valued product both in flavor and fragrance industries. The celery seed oil has been studied and 3-*n*-butyl phthalide, 3-*n*-butyl-4,5-dihydrophthalide (sedanenolide), and sedanolide have been reported as the major flavor components of the oil (Verghese, 1990; Choudhary and Kaul, 1992). Volatile compounds in celery leaf juice from harvest debris have also been studied (Buttkus, 1978). Phthalide enriched fraction from celery seed oil can be obtained by simple method that can be used for pharmacological applications. A patent has been filed for the preparation of phthalide enriched fraction from celery seed oil (Sowbhagya et al., 2004). Leaf oil, extracts of

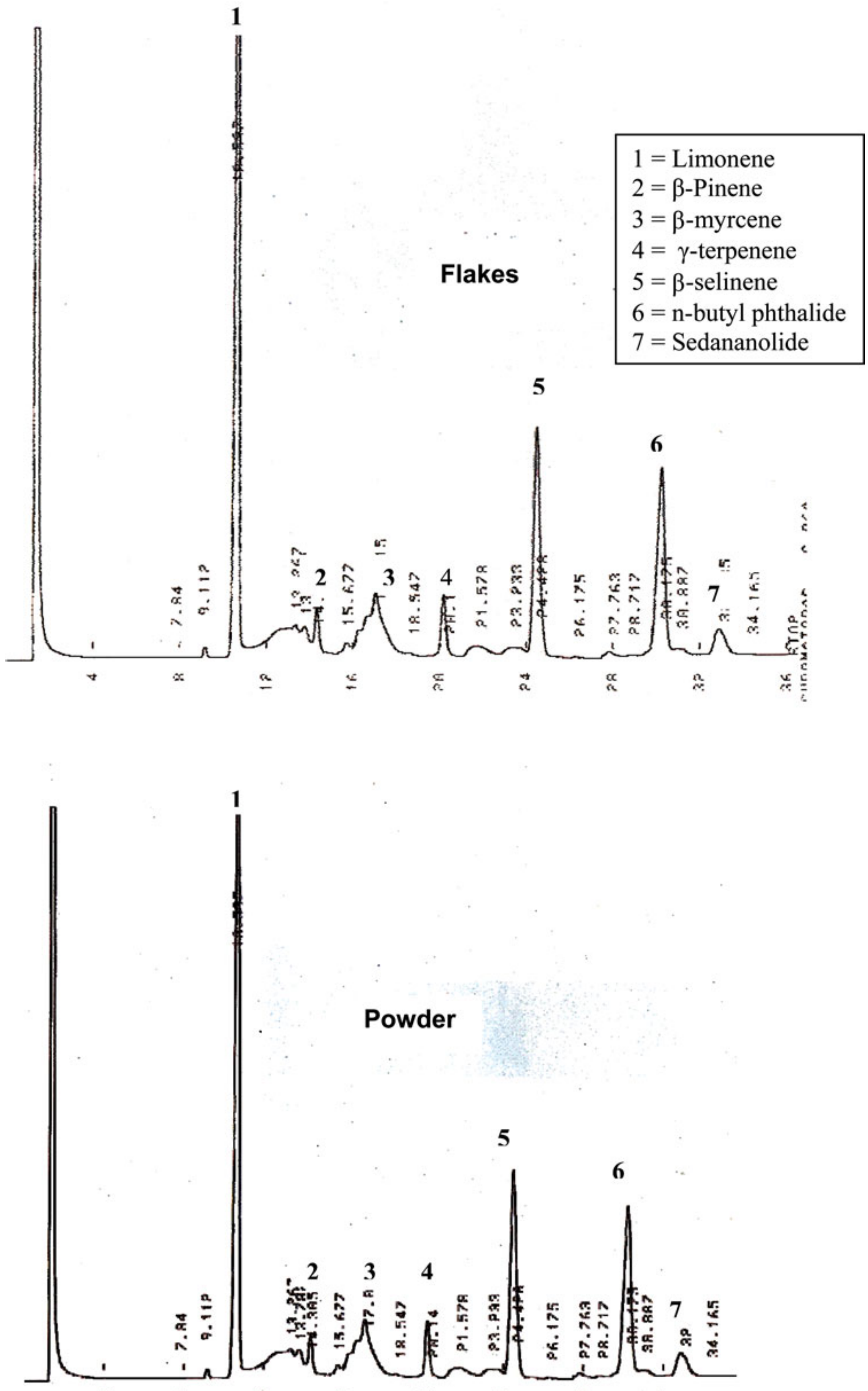

Figure 2 GC profile of celery volatile oil from flakes and powder. Adapted from Sowbhagya et al. (2007). (Color figure available online.)

Table 3 Standards for celery volatile oil and oleoresin

Parameters	Specification
Optical rotation 20°C	+45 to +78
Refractive index 20°C	1.4800–1.4900
Specific gravity (g) 30°C	0.8700–0.9100
Volatile oil content in oleoresin	20%

Source: E.O.A. No. 85.

seed and roots, and seed oleoresin are additional products from celery. Celery leaf oil contains more monoterpenoids and less sesquiterpenoids than the seed oil.

Celery oleoresin is a thick viscous product with 20–30% volatile oil, insoluble in water. Oleoresin is dispersed either in solid form on dextrose to obtain powder or in liquid form by adding in diluents such as propylene glycol for ease of usage in foods. Oleoresin consists of volatile oil, fixed oil, wax, resin, and artifacts that act as a fixative for the volatiles. The volatile oil content of the oleoresin is the quality parameter, since there is no major flavor compound present in the resin portion of the celery oleoresin unlike other major spice oleoresins.

2.7. Standards and Specifications for Celery, Essential Oil, and Oleoresin

The seeds must be free from moulds and insect infestation. They should be low in extraneous matter like stem, straw, and dust (<1.5%) and damaged and foreign seeds (<2.5%). They should have fresh taste and aroma and contain at least 1.5% of essential oil (Table 3). Specification for celery oil is prescribed by EOA (1978) that is presented in Table 4. For celery oleoresin, no specific phytochemical component is mentioned, but volatile oil content is specified and volatile oil blending to resin is done according to the customer's choice.

Table 4 Major carbonyl compounds (%) in fresh celery essential oil recovered by two different methods

Constituents	Batch distillation	Continuous distillation
t-Limonene oxide	0.50	5.0
c-Limonene oxide	10.0	5.0
Dihydrocarvone	5.0	1.5
Carvone	10.0	5.0
a-Ionone	1.0	2.0
N,Butyl-phenylketone	1.0	—
C,3-Hexenyl-l-acetate	0.25	—
Pinocarvyl acetate	0.50	5.0
Dihydrocarvyl acetate	—	1.0
t-carvyl acetate	20.0	25.0
c-p-1(7)8-Menthadienyl-2-acetate	2.0	3.0
Acetic acid	1.0	2.0
Tiglic acid	0.5	1.0
Angelic acid	—	0.5
3,n-Butylhexahydrophthalide	0.25	0.25
3,n-Butylphthalide	20.0	20.0
Sedanolide	5.0	5.0
Unidentified	21.0	15.75

Source: Wilson (1970).

Table 5 Low-molecular-weight carbohydrates in celery byproducts (% dwb)

Carbohydrates	Celery leaves and stalks	Stalks
Sucrose	5.97 ± 0.22	5.6 ± 0.15
Glucose	7.01 ± 0.30	11.7 ± 0.3
Fructose	7.57 ± 0.48	12.8 ± 0.37
Mannitol	13.33 ± 0.88	15.2 ± 0.44
Total sugar	33.88 ± 1.64	45.47 ± 1.24

Source: Adapted from Rupérez and Toledano (2003).

2.7.1. Celery Byproducts

A study on celery byproducts as a source of mannitol has been reported by Rupérez and Toledano (2003). Two types of celery residues from the industry, viz., (1) stalks, and (2) stalks plus leaves, were analyzed for soluble sugars and mannitol. Celery residues, viz., stalks alone and stalks plus leaves, were extracted with hot 85% ethanol to solubilize soluble sugars and mannitol. Low-molecular-weight carbohydrates in the extracts were identified and quantified by high-performance liquid chromatography (Table 5). Both celery residues were found to contain similar amounts of sucrose (5.7, 5.9%), but different ratios of hexose (glucose and fructose) to mannitol. Total sugar content and mannitol were higher in the stalks (45.5% and 15.2%, respectively) than in the stalk plus leaf residues (33.9% and 13.3%, respectively). Mannitol represented 33.5–39.3% of the total carbohydrate in celery wastes. The alcoholic extracts from celery residues are proposed as a natural source of mannitol and soluble sugars and alcohol-insoluble residue from celery byproducts could be further used for the preparation of dietary fiber-rich food supplements by the food industry. Similar observation on ethanol-insoluble residue form celery stalk has shown it to be a rich source of mannitol (Siddiqui, 1989). The ethanol-soluble residue showed major amounts of glucose, myoinositol, and sucrose. Mannitol is reported to be slowly and incompletely absorbed from the small intestine; it can also be considered as a potential prebiotic ingredient of functional foods. Celery is a rich source of mannitol and it comprises up to 50% of the total carbohydrate in the plant.

3. BIOACTIVITY

As a medicinal plant, celery has been used as an aphrodisiac, antihelmintic, antispasmodic, carminative, diuretic, laxative, sedative, stimulant, and tonic. The medicinal parts of the plant are roots, leaves and seeds. Preparations of celery are also used for blood purification, for regulating bowels movements for evacuation, glandular stimulation, and as a cure for gallstones and kidney stones (Bradley, 1992). Celery seeds are implicated in arthritic pain relief, for treating rheumatic conditions and gout (Satyavati et al., 1976; Bjeldanes and Kim, 1977; Chevalier, 1978). Nitrogenous compounds in celery seed oil have been reported to have effects on central nervous system (Satyavati et al., 1976). Even though high in sodium, celery is effective at lowering blood pressure because 3-*n*-butyl phthalide has been demonstrated to relax the smooth muscles that line blood vessels (www//Molecular Expressions phytochemical Gallery-butyl phthalide.html). Celery is an excellent source of vitamin C, a vitamin that helps to support the immune system. Over 20 scientific studies have concluded that vitamin C is a cold-fighter and vitamin C is also reported to prevent the free radical damage that triggers the inflammatory cascade, and is therefore also associated with reduced severity of inflammatory conditions, such as asthma, osteoarthritis, and rheumatoid arthritis. As free radicals can oxidize cholesterol and lead to plaques that may rupture causing heart attacks or stroke, vitamin C is beneficial to promoting cardiovascular health.

3.1. Antioxidant Activity

Antioxidant bioassays with crude extracts of celery were carried out on liposome oxidation by flourescence spectrophotometric method (Arora et al., 1998). Extracts of celery leaves and roots in four different solvents of different polarity, viz., ether, chloroform, ethyl acetate, *n*-butanol, and water, were studied for their potential protective action by in vitro and in vivo tests. Extracts of roots and leaves were found to be potential scavengers of OH and DPPH radicals, as well as inhibitors of liposomal peroxidation (Popovic et al., 2006). It is reported by the authors that all the extracts showed a certain protective effect, *n*-butanol extract showing the highest effect. The effect of different extracts on antioxidant systems in mouse liver and blood in combination with CCL_4 and without CCL_4 was studied. Combined effect of extracts with CCL_4 showed both positive and negative synergism, inducing or suppressing the impact of CCL_4.

3.2. Anti-Inflammatory Effect

Fractions have been isolated Apium graveolens Linn. seeds and tested for their from Antioxidant, cyclooxygenase and topoisomerase inhibitory (Momin & Nair, 2002). Feeding aqueous and butanol extracts of celery and study of the mechanism of the extracts on hypocholesterolaemic effect in genetically hypercholesterolaemic rats was studied (Tsi and Tan, 2000). Celery extracts have been reported to exhibit anti-inflammatory effect in rats evidenced by measuring the suppression of carageenan-induced paw edema (Al-Hindawi et al., 1989). But specific constituent responsible for the effect has not been identified. Extracts of celery seed have been evaluated for the treatment and prevention of inflammation and gastrointestinal irritation (Butters et al., 2002).

Specific herbal preparations containing phytochemicals from ginger, cayenne pepper, turmeric, yucca, devil's claw, nettle leaf, alfalfa, and celery seeds have been used to treat prophylaxis and in the therapy of joint and connective tissue disorders in vertebrates. *n*-Butyl phthalide the major flavor-impact compound of celery volatile oil is reported to be responsible for the above-mentioned health benefits (Rose and Chrisope (1999). In view of these health benefits of the phthalides of celery, and also the demand for newer sources of nutraceuticals, phthalide-enriched fraction from celery oil would be in high demand and useful for the treatment of hypertension and heart ailments. 3-n-butyl phthalide is also reported to be a muscle relaxant (Zasshi, 1989). There are very few reports on the separation of phthalides (Gold and Wilson, 1963; Uhlig et al., 1987) from celery oil.

3.3. Anticancer Effects

The phthalides from celery are the most significant bioactive compounds exhibiting many health benefits like protection against cancer, high-blood pressure, and cholesterol. Sedanolide has been reported to be the most active of the phthalides in the reduction of tumors in laboratory animals. Sedanolide and 3-*n*-butyl phthalide isolated from celery seed oil exhibited high activities to induce the detoxifying enzyme glutathione S-transferase (GST) in the target tissues of female mice (Zheng et al., 1993). After treatment with 3-*n*-butyl phthalide and sedanolide, the tumor incidence was reduced from 68% to 30% and 11%, respectively. About 67% and 83% reduction in tumor multiplicity was also observed with 3-*n*-butyl phthalide and sedanolide, indicating that 3-*n*-butyl phthalide and sedanolide were both active in tumor inhibition and GST assays exhibiting a correlation between the inhibitory activity and the GST-inducing ability. These results suggest that phthalides, as a class of bioactive natural products occurring in edible umbelliferae plants, may be effective chemo-preventative agents.

Methanolic extracts of celery seeds is reported to possess hepatoprotective activity. The extract was tested against di-(2-ethylxyl) phthalate (DEHP)-induced hepatotoxicity in rats (Jain et al., 2009). Oral administration of celery seeds extract 300 mg/kg body wt/day for six weeks prevented the rise in serum marker enzymes, viz., glutamate oxaloacetates transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT), alkaline phosphatases (ALP), and levels of bilirubin in DEHP-induced rats. Similarly, reduction in oxidative stress markers has been observed in rat testes when treated with *A. greaveolens* extract (Hamza and Amin, 2007).

Celery contains compounds called *coumarins* that help prevent free radicals from damaging cells, thus decreasing the mutations that increase the potential for cells to become cancerous (Murray, 2005). Coumarins also enhance the activity of certain white blood cells, immune defenders that target and eliminate potentially harmful cells, including cancer cells. Coumarin compounds also lower blood pressure, tone the vascular system, and are possibly effective when used in cases of migraines. Due to the high levels of potassium and sodium, celery-based juices when consumed after a workout can serve as great electrolyte replacement drinks. Studies have also shown that celery may help to lower cholesterol and prevent cancer by improving detoxification. Celery extract that contains 85% 3-*n*-butyl phthalide has been shown to be effective in the treatment of "rheumatism," the general term used for arthritic and muscular aches and pains. In addition, compounds in celery called *acetylenics* have been shown to stop the growth of tumor cells.

3.4. Antimicrobial Activity

Celery volatile oil has been shown to have antifungal activity, and it is active against many bacteria, viz., *Staphylococcus aureus*, *Staphylococcus albus*, *Shigella dysenteriae*, *Salmonella typhi*, *Streptococcus faecalis*, *Streptococcus pyogenes*, and *Pseudomonas solanacearum*. No activity was observed against *Escherichia coli* or *Pseudomonas aeruginosa* (Atta and Alkofahi, 1998).

3.5. Blood Platelet Aggregation and Antihyperlipidemic Acitvity

Inhibition of blood platelet aggregation by celery extract in vitro is reported (Teng et al., 1985). It is reported that the compound apigenin and not phthalides was responsible for the inhibition. Aqueous extracts of celery was found to reduce total cholesterol and low-density lipoprotein (Tsi et al., 1995). Aqueous celery extract was included with high-protein diet in one group of rats and another group of rats were fed with only high-protein diet for eight weeks. At the end of eight weeks, significant reduction in serum cholesterol, low-density lipoprotein cholesterol, and triglycerides was found in group of rats fed with celery extract supplement. Hepatic triglycerol lipase activity was found to be significantly lower in the celery-treated rats compared to control rats. Analysis of the aqueous extract of celery showed that it did not contain the active compound 3-*n*-phthalide that was previously reported to be responsible for lipid lowering action (Tsi et al., 1995). It could be due to other active principles of aqueous extract of celery on serum and lipid levels.

3.6. Effect on Kidney

Celery seeds have a direct action on the kidneys, increasing the elimination of water and speeding up the clearance of accumulated toxins from the joints, and benefits the arthritis condition (Buhner, 2007). Celery is administered with *Taraxacum radix* (Dandalion) to increase the efficiency of elimination by both the kidney and liver (www.curezone.com/cleanse/kidney/celery-seeds.asp).

3.7. Celery-Spent as a Source of Dietary Fiber

Celery-spent obtained after the volatile oil and oleoresin extraction contains protein, fiber, carbohydrates, and minerals, as the solvents used for oleoresin extraction do not extract the above-mentioned ingredients. Annually 1234 tons of celery-spent residue is obtained from spice oleoresins industries (Mathew, 2004) that does not find any commercial applications. A small portion of it is mixed with poultry feed and veterinary feeds. Most of it is used as a boiler feed for heat generation. Dietary fiber (DF) has been consumed for centuries and recognized as having many health benefits. Fiber intake through consumption of foods rich in DF is associated with reduction in cholesterol, increasing stool bulk, attenuating glycemic and insulin response, and improving laxation (Schneeman, 1999; Slavin, 2005). Diets with adequate fiber are less energy dense and larger in volume and bring a feeling of satiety sooner (Saris, 2003). Spent residue of celery as a new source of dietary fiber was studied (Sowbhagya, 2006). The spent residue was found to contain total dietary fiber (TDF) 60% with 52% insoluble dietary fiber (IDF), 7% soluble dietary fiber (SDF), 7% ash, 5% crude fat, 19% protein, and 9% starch. The micro structure of celery powder, celery-spent residue left after oil and oleoresin extraction, and insoluble and soluble fiber isolated from spent residue have been studied by scanning electron microscope (SEM; Sowbhagya et al., 2011). Scanning electron micrograph of celery powder before oil and oleoresin extraction showed few spherical-shaped starch granules within a fiber matrix (Fig. 3a) that after volatile oil and oleoresin extraction showed gelatinized starch granules (Fig. 3b). Insoluble fiber exhibits a coiled helix rod-like structure (Fig. 3c) and a porous smooth surface in case of soluble fiber (Fig. 3d). Any residual fat in the spent could be removed by giving a wash with hexane or ethanol. The spent residue from celery can be incorporated into various food formulations as a source of dietary fiber as well as a source of protein and minerals.

3.8 Antihypotensive Agent

The effect of 3-n-butylphthalide in reducing the hypertension and also as a vasorelaxant in spontaneously hypertensive rats were studied by Tsi and Tan, (1997). A 13-day intraperitoneal infusion of butyl phthalide at doses of 2.0 and 4.0 mg/day produced a transient hypotensive effect. The vasorelaxant property of butyl phthalide has been attributed by the authors to the blockade of calcium entry to receptor calcium channels therby reducing the systolic blood pressure of the rats.

4. USES OF CELERY

The ground seed is mixed with salt to produce “celery salt” that is used in flavoring fish, salads, and eggs. Celery with pepper powder is also available. Celery herb (leaves and stalks), seeds, volatile oil, and oleoresins are used to flavor canned soups, sauces, pickles, tomato products, and meats. Celery essential oil lends a floral-like odor to oriental perfumes to which it imparts warm and clinging notes (Lewis, 1984). Oleoresin of celery is widely used for flavoring of food. Celery is consumed both in fresh form and as infusion of seeds, powder, and extracts. The leaves are consumed as a salad in western countries. Celery seed is often used in pickling and it goes well in

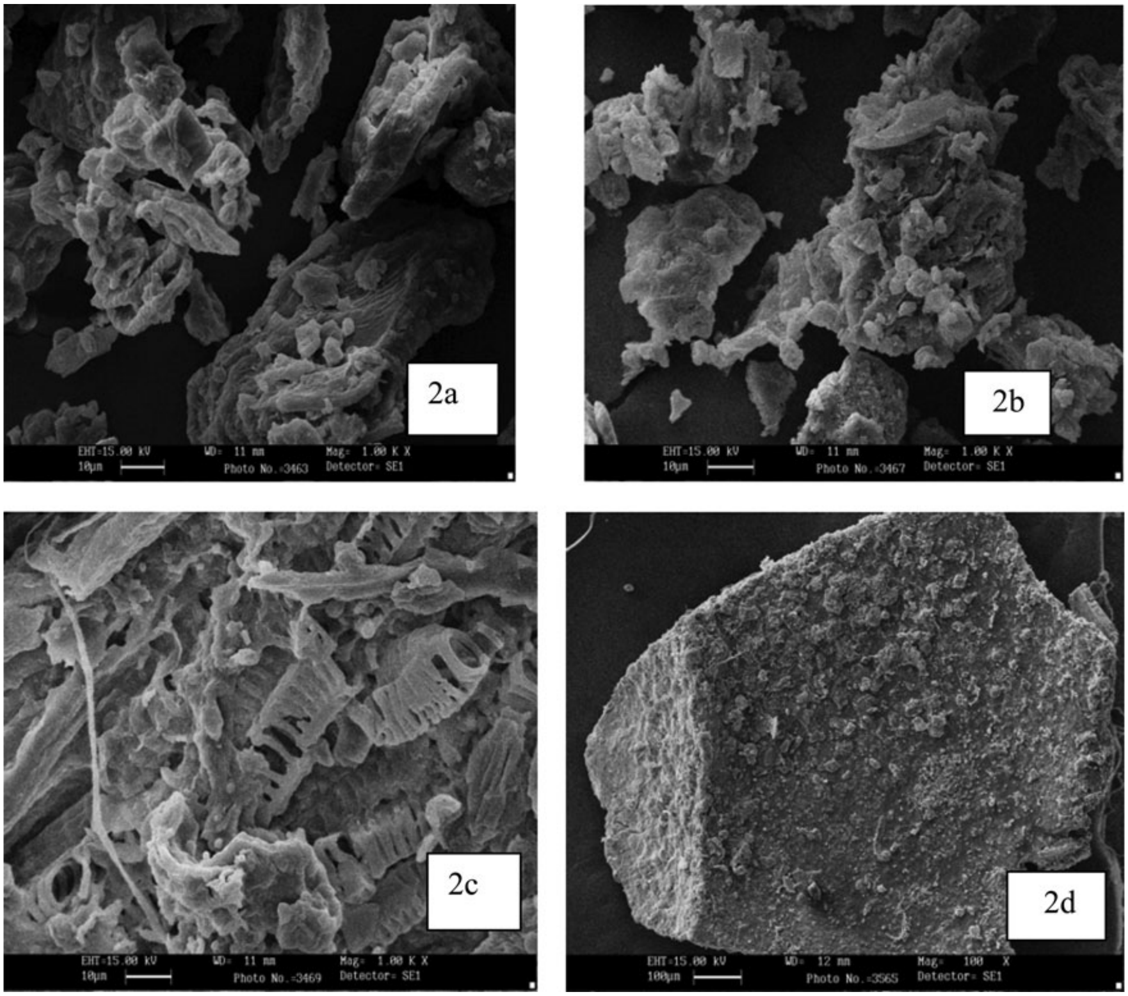

Figure 3 Scanning electron micrographs of celery powder (2a), celery spent residue (2b), IDF fraction (2c), and SDF fraction at lower (100×) (2d). Adapted from Sowbhagya et al. (2011).

preparation of bread, rolls, pastries, egg dishes, especially omelets, hamburger, stews, soup, chowder, meat loaf, stewed tomatoes, tomato juice, clam juice, tomato sauce, potato and green salads, salad dressings, tuna and salmon salad, vegetables, stuffings, sauerkraut, etc.

Celery seeds are also used for the health benefits, viz., as a stimulant and tonic in asthma and for liver diseases (Satyavati et al., 1976; Chevallier, 1998). As a domestic medicine, seeds are used as sedative and nerve stimulant. The celery seed oil has been successfully employed in rheumatoid arthritis (Soundararajan and Daunter, 1991–92; Chevallier, 1998).

5. CONCLUSIONS

Celery is a commercially important seed spice, valued for its medicinal properties. Value-added products from celery, viz., volatile oil and oleoresin, find application in food-processing industries. Celery of Indian origin dominates the world market. India exports celery seed to American and European markets. The production of celery seed oil is estimated around 50 ton/annum and half of it is produced in India. Other producers are the USA, Southern France, Holland, Hungary, Israel, and China. The Indian crop has to compete with seed produced in China and Israel where the seed and seed oil has local consumption to sustain the market to a certain extent. In India, about two-thirds of the produce is meant for export and the local consumption is meager. Owing to the higher amount of fatty oil (15%) present in celery seeds, large-scale grinding causes problems with flavor loss and requires newer methods for volatile oil extraction. Flaking or enzyme pretreatment of celery seeds is known to increase the yield (percent extracted) of volatile oil, which is a significant result especially from an economic viewpoint and can find application in spice industries. Presence of unsaturated fatty acids, viz., oleic acid and linoleic (60–70%) in celery oleoresin, leads to rancidity in oleoresin during storage. Methods to stabilize the oleoresin for longer storage periods need to be worked out. However, the presence of monounsaturated fatty acids (MUFA), especially linoleic acid in celery seeds and celery oleoresin, can provide us with the health benefits when the seeds are eaten.

Spent residue of celery can find application as a new source of dietary fiber in food formulations. Reports in literature show the evidence of celery and celery extracts possessing antidiabetic, antioxidant, antiplatelet aggregation, and cholesterol lowering effects. Celery contains vitamin C and several other active compounds that promote health, including phthalides, which help lower cholesterol, and coumarins, useful in cancer prevention. Limonene, present in celery, acts as a mild tranquilizer (wwww.theolivebrandh.com/herbs/celery.html). The calcium in celery seed helps calm tense nerves.

Newer methods of extraction of volatile oil from celery with an enhanced content of bioactive compounds could find commercial applications. Significance of natural products exhibiting health benefits is gaining a lot of importance and inclusion of celery in our daily diet could benefit us with health benefits mentioned above. Since celery is not a spice used in quantities similar to major spices like cumin, chilli, and turmeric, usage of celery should be popularized in different consumption forms, viz., as a coated product, table top for salad dressings, and as an ingredient of soups and ketchups. The effective dosage of the spice to get maximum health benefit for an individual also needs to be examined.

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