Ipomoea aquatica, An Underutilized Green Leafy Vegetable: A Review

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Abstract: Fruits and vegetables are emerging fast as most economical and nutritious global foods. They were declared as healthy foods of the millennium and also described as nutraceutical foods of the century, owing to their health benefits. Ipomoea aquatica Forsk., a commonly grown green leafy vegetable is a rich source of vitamins, minerals, proteins, fibers, carotenoids and flavonoids with many health benefits. It grows as a common weed in lakes and fresh water ponds but it is usually neglected because of lack of complete knowledge about this green leafy vegetable. This study describes useful information about I. aquatica, current research carried out so far and some of the medicinal properties identified and explored. This plant can be used as a natural source and as a nutraceutical substitute or as a functional food.

Key words: Ipomoea aquatica, bioactive compounds, antioxidant activity, hypoglycemic, anticancer

INTRODUCTION

Food science has a growing literature about fruits and vegetables imparting greater benefits to humans. Considerable epidemiological evidence suggests an association between consumption of a diet high in fruits and vegetables and decreased risk of cardiovascular diseases, hypertension, diabetes, stroke and various forms of cancer (Brandt et al., 2004; Craig, 1999). Although fruits and vegetables account for only 10% of total calories consumed, they make a significant contribution to overall health. Fruits and vegetables have a regular place in traditional Indian cuisine.

Among various types of vegetables, leafy vegetables are most commonly consumed in ancient Indian daily diet. The importance of leafy vegetables in the developing countries has been recognized only now due to their nutritional and medicinal value. Green leafy vegetables occupy an important place among food crops as these provide adequate amounts of crude fiber, carotene, a precursor of vitamin A, vitamin C, riboflavin, folic acid and mineral salts like calcium, iron, phosphorus etc. They are also fair sources of proteins, containing about 2-7% and they are equal to legumes, soybeans or whole egg (Aletor et al., 2002; Rao et al., 1990). They form cheap and best source of food. Green leafy vegetables are highly seasonal and are available in plenty at a particular season and can be easily cooked. However, edible green leafy vegetables appear to be underutilized throughout the world and, in some area, may even be diminished in use. Green leafy vegetables are rich source of a number of micronutrients and phytochemicals and it was the phytochemicals that appeared to provide much of the disease fighting power. In this context, this study provides some useful information of I. aquatica, about its nutritional importance, current work carried out and some important medicinal properties.

Classification: Ipomoea aquatica Forsk. belongs to the Class: Magnoliopsida; Order: Solarales, Family: Convolvulaceae; Sub class: Asteridae (Pullaiah, 1998).

Botanical description: I. aquatica is an aquatic or semi aquatic plant, trailing or floating, herbaceous, sometimes annual or perennial, with long, hollow stem possessing large number of air passages and rooting at the nodes, found throughout India (Fig. 1). Leaves are elliptic or ovate-oblong, cordate; flowers are infundibuliform, 2-2.5 cm long, white or pale purple, solitary; fruit is a capsule (Anonymous, 1959; Edie and Ho, 1969; Gamble, 1921; Payne, 1956; Synder et al., 1981).

I. aquatica is found trailing on moist soil or mud along the margins of stagnant streams, fresh water ponds, ditches, marshes and wet rice fields; sometimes found floating on water bodies. It occurs both in wild and cultivated state and is easily propagated by cuttings. It
carbohydrate 4.3%, mineral matter 2%, nicotinic acid: 0.6 mg/100 g; riboflavin: 120 mg/100 g; vitamin C: 137 mg/100 g; vitamin E: 11 mg/100 g and ash: 1.4% (Anonymous, 1959). The young terminal shoots and leaves of I. aquatica are eaten as green leafy vegetable and in salads (Ismail et al., 2004) and as fodder (Phimmasan et al., 2004). I. aquatica leaves are also very rich in proteins (Ngamsaeng et al., 2004), carotenoids (Chen and Chen, 1992), amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, leucine, tyrosine, lysine, histidine and arginine (Rao and Vijay, 2002), minerals like sodium, potassium, calcium, iron, magnesium and zinc (Duc et al., 1999), sugars like glucose, fructose, sucrose (Wills et al., 1984), fiber, lipids and fats (Imbs and Pham, 1995), organic acids like malic acid, citric acid, oxalic acid (Wills et al., 1984), vitamins (Duc et al., 1999), starch (Candlish et al., 1987), polyphenols like myricetin, quercetin, luteolin, apigenin, kaempferol (Chu et al., 2000; Daniel, 1989; Mean and Mohamed, 2001), dihydroquercetin glycoside (Prasad et al., 2005a) and ash (Ogle et al., 2001) contents.

Nutrition: Moisture, nitrogen, protein and amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cysteine, valine, methionine, isoleucine, leucine, tyrosine, lysine, histidine and arginine content of I. aquatica by Sutaria and Diego (1982) were estimated using AOAC methods. Alpha-tocopherol content of I. aquatica with other leafy vegetables were analysed by Candlish (1983). Wills et al. (1984) studied vitamins like vitamin C, thiamin, riboflavin, niacin, protein, fat, sugars like glucose, fructose, sucrose, starch, dietary fiber, organic acids like malic acid, citric acid, oxalic acid, ash and minerals like sodium, potassium, calcium, iron, magnesium and zinc contents for 15 Chinese vegetables including I. aquatica. Candlish et al. (1987) studied the dietary fiber (non-cellulose polysaccharide, cellulose, lignin) and starch content in vegetables that are extensively grown and consumed in Southeast Asia including I. aquatica. Rao et al. (1990) estimated the lipid contents like non polar lipids, glycolipids, phospholipids, fatty acids, amino acids like aspartine, threonine, serine, glycine, proline, alanine, leucine, tyrosine, histidine, aspergine, arginine, minerals like calcium, magnesium, iron, zinc and copper of I. aquatica.

Imbs and Pham (1995) analyzed total lipids, fatty acid, triglycerides content and phospholipid content of I. aquatica. Iron and vitamin C content of I. aquatica grown in three sites of Vietnam were investigated by Duc et al. (1999). The nutritional value of I. aquatica with yielding crops such as rice, sugarcane and maize were compared by Munger (1999). It is urged that investment in crops such as I. aquatica may be a suitable and cost-effective way to supplement the caloric and nutritional

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**Fig. 1: Ipomoea aquatica in its natural habitat**

grows rapidly producing dense masses of foliage within a few weeks of planting. It is one of the most popular green leafy vegetable. Its commonly called as aquatica morning glory, Chinese water spinach, kangkong, morning glory, swamp cabbage, swamp morning glory, water convolvulus, water spinach (Anonymous, 1959; Candlish et al., 1987; Chen et al., 1991; Edie and Ho, 1969; Payne, 1956; Synder et al., 1981; Wills et al., 1984).

**Origin and distribution:** I. aquatica is supposed to be originated in China (Edie and Ho, 1969). It is distributed throughout India, Sri Lanka, Tropical Asia, Africa and Australia (Kritkar and Basu, 1952). The plant is grown widely as weed in India and USA (Anonymous, 1959; Reed, 1977) while in South East Asia like Malaysia, China, Hong Kong, Singapore and Indonesia, the plant is grown commercially (Candlish et al., 1987; Chen et al., 1991).

**Composition:** The leaves of I. aquatica contain the following: moisture 90%, protein 3%, fiber 0.9%, fat 0.4%,
value of current crop production. Micronutrient composition like ash, calcium, iron, zinc, carotenes like α and β carotenes by Ogle et al. (2001) were determined. Iron, calcium, β carotene, ascorbic acid and oxalic acid content of *I. aquatica* consumed by the tribals of Purnia district of Bihar, India were analyzed by Rao and Vijay (2002). The dieting pattern of rabbits fed with water spinach were investigated by Phimmasan et al. (2004). Ngamsaeng et al. (2004) analyzed water spinach as protein supplements for ducks feed as basal diet.

**Carotenoids:** Ortaliza et al. (1969) estimated the carotene contents and its availability of *I. aquatica*. The effects of *I. aquatica* on cholesterol metabolism in rats were studied by Chen et al. (1984). Chen et al. (1991) characterized the major carotenoids in water convolvulus (*Ipomoea aquatica*) by open-column, thin layer and high performance liquid chromatography. Comparing the absorption spectra and retention time with reference standards the compounds were identified as β-carotene, cryptoxanthin, lutein, lutein epoxide, violoxanthin and neoxanthin. Carotene composition and contents of *I. aquatica* were analyzed by Tee and Lim (1991) by AOAC and HPLC methods. They found that AOAC method gave a falsely elevated result, whereas the HPLC method successfully separated the major carotenoids. The carotenoids identified were lutein and β-carotene and were compared to that of reference standards.

Carotenoids and chlorophylls in *I. aquatica* were determined by Chen and Chen (1992) using liquid chromatography. These carotenes and chlorophylls were analyzed by High Performance Liquid Chromatography (HPLC). Fourteen peaks were detected in HPLC, of which 12 pigments were identified. These pigments include neoxanthin, violaxanthin, cryptoxanthin, lutein epoxide, lutein, cis-lutein, chlorophyll b, chlorophyll b', chlorophyll a, β-carotene and cis β-carotene. These samples were then compared with standards by thin layer chromatography.

Tee et al. (1996) investigated the biological utilization of carotenoids of *Ipomoea aquatica* using rats and found bioavailability of the major carotenoids was high, as evidenced by the accumulation of retinol of the experimental rats in relation to crystalline retinol concentrate. Wills and Rangga (1996) analyzed carotene contents of *I. aquatica* by reverse phase HPLC and gradient elution. The carotenoids identified were zeaxanthin (Fig. 2a), lutein (Fig. 2b), anthraoxanthin, flavoxanthin, auroraxanthin, luteoxanthin, neoxanthin (Fig. 2c), β-carotene (Fig. 2d), violoxanthin (Fig. 2e), cryptoxanthin (Fig. 2f), neoxanthin a and neoxanthin b. These samples were compared to standards and identified. Provitamin A and carotenoids from *I. aquatica* of different maturity and origin were investigated by Hulshof et al. (1997). The carotene contents were different when collected from different places. Also, the carotene content of mature plant was higher compared to that of young plants. Provitamin A carotenoid content of *I. aquatica* at different maturity and origin was reported by Paul et al. (1997).

**Flavonoids:** Daniel (1989) estimated the polyphenol contents of *I. aquatica* and identified quercetin 3'-methyl ether (Fig. 3a), quercetin 4'-methyl ether (Fig. 3b) and anthocyanins. Flavonoid contents of *I. aquatica* like myrcetin, quercetin, luteolin and apigenin content were

![Fig. 2: Carotenes from Ipomoea aquatica (a) Zeaxanthin, (b) Lutein, (c) Neoxanthin, (d) β-carotene, (e) Violoxanthin and (f) Cryptoxanthin)](image-url)
Fig. 3. Flavonoids from Ipomoea aquatica. (a) Quercetin 3'-methyl ether, (b) Quercetin 4'-methyl ether and (c) 7-O-β-D-glucopyranosyl-dihydroquercetin-3-O-α-D-glucopyranoside

identified by Chu et al. (2000). Chlorophylls of I. aquatica were investigated by Miean and Mohamed (2001). Prasad et al. (2005a) isolated a 7-O-β-D-glucopyranosyl-dihydroquercetin-3-O-α-D-glucopyranoside (Fig. 3c) and it was characterized using UV, MS and NMR data.

Alkaloids: Seven aliphatic pyrroolidine amides with branched and linear saturated C_{13}-C_{16} acyl moieties were detected by Tofern et al. (1999) in the vegetative part (stem and leaves) of I. aquatica. One of the compounds was isolated and characterized as 1-(14-methylhexadecanoyl) pyrroolidine and compared with synthetic compound. Yajima and Yabuta (2001) investigated the synthesis and configuration of a novel pyrroolidine amide namely 1-(14'-methylhexadecanoyl) pyrroolidine from I. aquatica.

Storage studies: Kailasapathy and Koneeshan (1986) studied the loss of ascorbate content in eight leafy vegetables including I. aquatica due to wilting, from harvest up to a period of 24 h at environmental (24.7-25.8°C) and under refrigeration (4.4°C) temperatures. Quality changes like browning and changes in leaf and stem tissues of I. aquatica during storage at various temperatures (1 and 20°C) was analyzed on 5th day by Hirata et al. (1987). The structural changes in leaf and stem tissues of I. aquatica in relation to chilling injury and browning were investigated by Ose et al. (1990).

Processing: Candlish (1983) suggested that steaming of I. aquatica had highest carotene content than that of fresh and boiled one. The presence of cis-isomers of β-carotene in I. aquatica were examined before and after traditional Indonesian ways of cooking by Van der Pol et al. (1988). Yield of carotenoids of I. aquatica were analyzed by Chen and Han (1990) under different methods of cooking. Mazrizal et al. (1997) reported the retention of vitamin C, iron and β-carotene in I. aquatica under different cooking methods. Total carotenoid and β-carotene contents during processing like cooking, sun drying, frying and fermentation were investigated by Speck et al. (1988). Van der Pol et al. (1988) examined and compared the cis-carotene isomers (α-carotene, β-carotene, neo-β-carotene, neo-U-β-carotene) contents of I. aquatica before and after cooking. Mazrizal et al. (1997) studied the retention of β-carotene of I. aquatica when prepared using different cooking methods like boiling, microwave steaming and frying.

Tissue culture studies of Ipomoea aquatica: Effect of light on growth and chlorophyll formation of I. aquatica
hairy roots were investigated by Masahiro et al. (1996). Methods for introducing foreign genes for *I. aquatica* and regenerating the plant by Masanori et al. (1997) were developed. The method comprises co-cultivating the nodes of the explant with *Agrobacterium tumefaciens* carrying the target foreign gene. Hirofumi et al. (2000) followed the development and characterization of a phototrophic cell line of *I. aquatica* hairy roots. The derived phototrophic hairy roots had high chlorophyll content and activities of 1,5-ribulose-biphosphate carboxylase content were more than those of the parent plant. Ninomiya et al. (2003) investigated the changes in chlorophyll content in phototrophic hairy roots of *I. aquatica*. Callus initiation and its antioxidant activity of *I. aquatica* was compared with that of the mother plant and it was found that the antioxidant activity was high in callus cultures (Prasad et al. 2006).

**Antioxidant studies:** Ismail et al. (2004) estimated the antioxidant and phenolic contents of *I. aquatica*. Antioxidant activity of leaf extracts and purified compound isolated from *I. aquatica* were determined by Prasad et al. (2004, 2005 a) by DPPH, metal chelation and lipid peroxidation methods.

**Medicinal importance:** In Ayurveda (Indian traditional medicine), the extracts of leaves of *I. aquatica* are orally administered to alleviate the disorders like jaundice and nervous debility. This plant is used medicinally in Southeastern Asia. It is effectively used against nosebleed and high blood pressure (Duke and Ayensu, 1985; Perry, 1980). The juice of *I. aquatica* is used as emetic in cases of opium and arsenic poisoning (Anonymous, 1959; Chopra et al., 1956). Dried juice has purgative properties (Anonymous, 1959; Chopra et al., 1956; Nadkarni, 1954). Leaves and stems are said to be cooling. In Assam, the plant is given for nervous and general debility (Anonymous, 1959; Chopra et al., 1956). It is used also for piles (Anonymous, 1959), as anthelmintic (Anonymous, 1959; Nadkarni, 1954), used in leucoderma, leprosy, jaundice and liver complaints (Nadkarni, 1954).

This plant is supposed to possess an insulin-like principle according to indigenous medicine in Sri Lanka (Jayaweera, 1982). The medicinal uses of hitherto report includes: effect on liver diseases (Badruzzaman and Husain, 1992; Nadkarni, 1954), eye diseases (Jain and Verma, 1981), constipation (Samuelsson et al., 1992) and the inhibition of prostaglandin synthesis (Tseng et al., 1992). MacKean et al. (1997) demonstrated moderate antimetabolical activity of *I. aquatica* against pine wood nematode, *Bursaphelenchus xylophilus*. The aqueous extract of this plant also possess hypoglycemic effect (Malalavidehane et al., 2000, 2001, 2003). This plant also possesses antioxidant activity (Prasad et al., 2004, 2005 a). This plant also shows moderate anticancer activity against Vero, Hep-2 and A-549 cancer cell lines (Prasad et al., 2005 b).

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