Pharmacology and Phytochemistry of underexploited tuber crops: A review

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Abstract
Tuber crops play an important role in food security, nutritional security and climate change adaptation. These crops are essential components of stable daily diet in many under developed and developing countries around the globe and comprises of major and underexploited minor tuber species. Among these crops, the major edible species include cassava, sweet potato, yams, Chinese potato, canna, arrowroot, starichy Curcuma and aroids and minor non-edible medicinal crops include Coleus forskohlii, wild Dioscorea, wild amorphophallus species etc. These medicinally important tuber crops possess pharmacologically active principles and possess important medicinal properties. Over the past few decades, there has been observed significant revival of interest among the people on various natural products as powerful antioxidants, bioactive compounds and natural drugs, therefore current research on natural products remains the main means of discovering potential principle bioactive health compounds in the existing unexplored tuber species. The main objective of this review is to cover the details of local and traditional uses of the tuber species which includes pharmacology, photochemistry and toxicology of medicinally important minor underexploited tuber crops.

Keywords: Tuber crop, antioxidant, bioactive compounds, drug

1. Introduction
Root and tuber crops constitute the second largest group of cultivated species, after cereals in tropical countries and occupy prime position in the food security, due to their high carbohydrate content and calorific value (Lebot, 2009) [55]. In India there is an existing rich genetic diversity of tropical root and tuber crops particularly aroids, yams and several minor tuber crops (Chuakul et al., 2000; Keardrit et al. 2010) [26, 47]. They take special status during natural famines and calamities due to their natural adventitious root systems. The major tuber crops comprise of cassava, sweet potato, yam species, aroids and minor tuber crops include Amorphophallus konjac, wild Dioscorea species, Coleus, Costus, Typhonium, Tacca, Arrowroot, Canna, Chinese potato, Cocoyam, Ceropogia, Alciosia, winged bean, yam bean, swamp taro, giant taro and starichy Curcuma species (Parra et al., 2001 and Neviani et al., 2005) [84, 73]. Leaves of many tropical tuber crops are rich sources of many important bioactive principles that could contribute significantly for eradication of many dreadful diseases in the world. Minor tuber crops also contain several medicinally important bioactive principles in different parts such as tubers, stems and leaves besides the tubers serving as storehouses of different carbohydrates. Sujatha and Renuga (2013) [107] reported unexploited medicinal and edible tubers from forty two settlements of Tribals from Pechiparai Social forest in Kanyakumari District, Tamil Nadu, India and documented the traditional knowledge of medicinal tuber crops of those particular tribal communities (Tholkappiyavathi et al., 2013) [109]. Recently, global interest has been focused towards the medicinal plants as potential sources of many useful drugs. The traditional uses and toxicological studies of minor and underexploited tropical tuber crops are shown in Table 1. Main aim of this review is to address the different types of minor and underexploited tuber crops, their local and traditional uses, species pharmacology, photochemistry and toxicology of medicinally important crops etc.
### Table 1: Traditional uses and toxicology studies of minor and underexploited tropical tuber crops

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Traditional uses</th>
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<th>Toxicology studies</th>
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| Arrow root  | Maranta arundinacea | - Traditionally the tuberous rhizomes are used in the treatment of diarrhoea  
- The edible tuberous rhizomes are rich in starch and are also a commercial source of fine grade starch used often in weaned foods and biscuits | Nishaa et al. 2012 [74] | Highest dose of 400µg/mL of methanolic extract of *Maranta arundinacea* was not toxic to mice, tested by brine shrimp lethality test | Rahman et al. 2015 [92] |
| Coleus      | Coleus sp.       | - *C. barbatus* leaves are used to get relief from stomachalgia in Africa and Brazil  
- Whole plant of *C. vettiveroides* has been used to stop the vomiting and nausea in India.  
- Forskolin is also used in the preparation of medicines preventing hair greying and restoring grey hair to its normal colour  
- *C. aromaticus* leaf juice is carminative when mixed with sugar, given to children in colic  
- Forskolin also showed that it was extremely safe with an oral LD50 of 3100 mg/kg  
- Sclareol isolated from *C. forskohlii* reported to be non-cytotoxic to resting human peripheral blood mononuclear leukocytes and have LD50 > 5mg/kg in rats | Soni and Singhai, 2012 [105] | - | Parra et al., 2001 and Neviani et al., 2005 [84, 73] |
| Costus      | *Costus* species | - In India rhizomes of Costus are used for cold, pneumonia and rheumatism in Ayurvedic treatment, diabetic patients are advised to chew 2-3 leaves per day  
- In Traditional medicine, *C. igneus* is used to promote longevity, reduces fever, asthma, bronchitis, treat rash  
- Roots are used against snake bite  
- Leaf infusion or decoction is utilized as a sudorific or in a bath for patients with high fever  
- Acute and subchronic toxicity studies of aqueous leaf and stem bark extract of *Costus afer* in mice | Brackenridge et al., 2002 [13] | - | Udem and Ezeasor, 2010 [110] |
| Ceropegia   | Ceropegia pusilla | - *Ceropegia pusilla* tubers are used in Indian Ayurvedic drug preparations that are active against ulcers, inflammation  
- The tubers of *Ceropegia* species are used by tribal women to promote fertility and vitality | Adibatti et al., 1991 [5] | - | - |
| Starchy Curcuma species | *Curcuma* zedoaria, *C. aromatica*, *C. malabarica*, *C. amada*, *C. brog*, *C. raktakanta* | - Traditionally *Curcuma zedoaria* has been used for treatment of many diseases such as stomach diseases, blood stagnation, hepato protection, diarrhoea, coryza, dermatosis disorders and rheumatism and promoting menstruation.  
- Dried rhizome and leaves of *Curcuma caecia Roxb* are used for treatment of piles, leprosy, asthma, cancer, wounds, fever, impotency, fertility, tooth ache, vomiting and allergies in North-East and Central India. | Tholkappiyavathi et al., 2013 [109] | Curcuma xanthorrhiza ethanolic extract showed absence of toxic effects which could compromise the medicinal use of this plant in folk medicine | Devaraj et al., 2010 [27] |
| Giant taro | Alocasia macrorrhiza | - Its traditional medicinal uses have been recorded in the folklore, as | Acharya et al. 2014 [3] | Among ten isolated compounds, hyrtiosin B showed the toxicity | Ellil, 2014 [30] |
Konjac  

Amorphophallus konjac
- Detoxification, tumour-suppression, blood stasis and phlegm liquefaction
- Konjac gel has been used for treatment of asthma, cough, hernia, breast pain, burns and skin disorders
- Konjac flour used as natural insect repellent and as animal fodder by the indigenous people in Southern China
- Traditionally, corms are washed, peeled, sliced, dried and ground to produce konjac flour which is consumed in the form of cake (or gel) after boiling the flour with plant ash

Niwa et al., 2000; Brown, 2000; Long, 1998; Chan et al., 2010

Khonjac gel has been used for treatment of asthma, cough, hernia, breast pain, burns as well as haematological and skin disorders

Murti et al. (2010)

Taccas

Tacca leontopetaloides, T. aspera, T. paxiana, T. plantaginea, T. subflabellata, T. chantrieri
- Rhizomes of T. integrifolia are used for improving sexual function and controlling blood pressure in Thai herbal medicine
- In China, Tacca species has been used for treatment of hepatitis, gastric ulcer, enteritis etc.
- In South-east Asia, rural people has been used T. chantrieri rhizome decoction alone or combination with other herbs, to relieve pains of the body and stomach, and as an antidote for food poisoning

Chuakul et al., 2000; Keardrit et al., 2010

Sianipar et al., 2013; Mohan et al. 2008; Alfarabi et al., 2015

Typhonium

Typhonium flagelliforme, T. trilobatum
- T. flagelliforme tuber has been used as important ingredient in the herbal cancer treatments
- Hexane phase of the petiole extracts of the T.flagelliforme found highly toxic to A. salina (LC50 = 762.08µg ml-1)
- T.flagelliforme tuber has a cytotoxic activity against cancer cell growth
- The tuber protein extract from T.flagelliforme showed anti-proliferative effect against MCF-7 and nontoxic for fibroblast cells until 100ppm

Choo et al. 2001a

Sianipar et al., 2013; Mohan et al. 2008; Alfarabi et al., 2015

Swamp taro

Cryptosperma merkusii
- Swamp taro corms are can be roasted boiled, baked whole, mashed or grated and combined with coconut milk to make into pudding

- - -

Winged bean

Psophocarpus tetragonolobus
- In New Guinea, the pods and the edible tubers are considered roborant
- Traditionally leaves and seed are eaten by rural folk to cure skin sores such as boils and ulcers
- Winged bean protein hydrolysate not showed any cytotoxic effects on NIH/3T3 mouse fibroblast cell, so it is safe in terms of genotoxicity and cytotoxicity, it can be used in pharmaceutical and food industries as functional ingredient

Stopp, 1962; Perry, 1980

Kawanding et al., 2015

Wild yam species

Dioscorea species
- In Nigeria, D. bulbifera used as powered bulbils soaked in water, which is effective against reducing the blood pressure
- The leaf of aerial yam is used as a

Adeniran and Sonibare, 2013; Gao et al., 2002; Gao et al., 2001

Boiled water yam tubers (Dioscorea alata) were reported with low anti-nutritional compounds like alkaloids, saponins, flavonoids and tannins

Ezeocha and Ojmelakwe, 2012

on Hep-2 with IC50 of 4.65 µg/ml

Asthma and occupational exposure to airborne powder produced during the manufacture of konjac flour

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2. Minor and underexploited tuber crops and their Medicinal properties

2.1. Konjac (Amorphophallus konjac)

It’s originated in South East Asia and is an important commercial crop grown in China, Japan, Indonesia and subtropical regions of Asia. It is a large, perennial exotic Asian plant, producing elongated centre corm and single large leaf. Though it has long been used as source of flour in China and Japan, it is becoming increasingly popular as a health food in many countries (Mishra, 2013) [62].

2.1.1 Ethno-Pharmacology and Phytoconstituents

Konjac has been used as traditional medicine for treatment of cough, breast pain, asthma and skin disorders. Konjac can trigger absorption and digestion of protein and other nutritional substances, keeps the intestine clean, and assists in bowel movement. It also contains 9.7% of crude protein, minerals such as calcium, phosphorus, iron, zinc, manganese, chromium and copper (Chen et al. 2003) [20]. Presence of glucomannan, trigonelline, saponins, riboflavin, β-carotene, thiamine, choline, niacin, serotonin, betulinic acid, tricontane, lupeol, stigmasterol, sitosterol and its palmitate etc. has been reported in konjac corms (Niwa et al. 2000) [78].

2.1.2 Phytochemistry and Phytopharmacology

Li et al. (2005) [57] reported the presence of small amount of alkaloids (trigonelline), glucomannan and saponins at dormant stem base. Fresh konjac corm contains riboflavin, β-carotene, thiamine, choline, niacin and as well as serotoninand its derivatives namely cis-N-(p-coumaroyl) serotonin and trans-N-(p-coumaroyl) serotonin (Niwa et al. 2000) [78]. Corms have unique feature of containing high levels of glucomannan (over 45%), which is the best known natural edible and water-soluble fibre (Nishinari and Yoshimura, 1999) [77]. Regular consumption of glucomannan is reported to reduce total cholesterol, prevent constipation, reduce serum insulin, and regulate the levels of blood sugar and lipid metabolism, promote body weight loss and immune functions of human body and also function as a mycoxin adsorbent. Corms also possess potential pharmacological properties such as antidiabetic activity (Chen et al. 2003) [20], anti-obesity activity (Keithley et al. 2005) [48], laxative activity (Chen et al. 2006) [21], anti-inflammatory activity (Onishi et al. 2004) [81] and prebiotic activity (Li et al. 2005; Niwa et al. 2000) [57, 78].

2.2 West Indian Arrowroot

Arrowroot (Maranta arundinacea), synonym west Indian arrowroot is a tropical, perennial tuberous plant belonging to the family Marantaceae, well known for its edible starch that finds wide application as infant food. It produces ginger like leaves, perennial rhizome and edible rhizomes contain the easily digested edible starch.

2.2.1 Ethno-Pharmacology

Arrowroot flour has a nutritional composition of 5.0% soluble dietary fibre, 8.7% insoluble dietary fibre, 0.14% protein, 25.9% amylase, 0.84% fat, 11.9% water and 0.58% ash (Kumalasari et al. 2012) [52].

2.2.2 Phyto constituents

Arrowroot comprised of different phytochemicals like flavonoids, alkaloids, tannins, glycosides, steroids, phenols, cardiac glycosides and saponins.

2.2.3 Phytochemistry

The GC-MS analysis of the ethanolic extract revealed the presence of 49 compounds such as cyclohexanone, 2-hydroxy- cyclopenta-2,4-diene, 2,3-dimethoxy-succinicacid dimethyl ester, 5-diethylsilanoloxy-4-ethyl-2 phenyl-3a,4,7a-tetrahydro-isoindole-1,3-dione, triethyl-(3-methyl sulfanyl-1-vinyl-pent-1-enyloxy)-silane, (2-Methyl-thiiranyl)-methanol, 2-tert-butoxy-tetrahydro-furan, cis-2-(7-octynyl)cyclohexanol, tetradeacne, cyclohepta-2,4,6-triene-carboxylic acid ethyl ester, benzyl-butylic amine, 2,6-dimethoxy phenol, 2-methoxy-3-methyl-benzene-1,4-diol and 2,4-dimethoxy phenol (Nishaa et al. 2013) [74].

2.2.4 Phytopharmacology

Arrowroot has been described as a potent source of natural antioxidants and is also reported to possess immunostimulatory effects in vivo as well as in vitro in rats and has anti-inflammatory and antiseptic properties (Kumalasari et al. 2012) [52]. The arrowroot tuber extract
exhibited antioxidant activity against, ABTS, DPPH, nitric oxide and hydrogen peroxide radicals (Nishaa et al. 2012) [75]. Rahman et al. (2015) [93] reported the remarkable anti diarrheal activity of methanolic leaf extract of arrowroot with slight cytotoxic effect.

2.3 *Ceropegia* species

*Ceropegia pusilla* is an endangered medicinal tuber crop belonging to the family Asclepiadaceae, with 200 species distributed in tropical and subtropical regions of old world, of which 48 species are distributed in India. It gained importance taxonomically and ethnobotanically.

2.3.1 Ethno-Pharmacology

The sweet-sour leaves are edible and consider being tonic and digestive, complete plant extract is used as an antidote for snake bite. *Ceropegia bulbosa* is used for the treatment of cold, sneezing and eye diseases in India (particularly in Bihar region).

2.3.2 Phytoconstituents

The presence of secondary metabolites like triterpenes, alkaloids, tannins, glycosides, saponin, flavonoids, steroid and phenols are reported in the tubers. The tubers are edible, contains starch, sugar, fats, crude fibre and medicinally important alkaloid ‘ceropegin’ (Jain and Defillips, 1991) [43].

2.3.3 Phytochemistry

Ceropegia is an alkaloid present in the edible tubers of Ceropegia that is used for preparation of many ayurvedic drugs and is effective against eye diseases, dysentery, diarrhoea, syphilis, cold and sneezing. Kalimuthu and Prabakaran (2013) [44] screened methanol extract of *Ceropegia pusilla* tuber in vitro, revealed the presence of potential phytochemicals such as 1, 2-diphenyl-1-butanol (8.04%) (E)-1, 2-bis (2-bromo-4, 5-dimethoxyphenyl)-N, N-dimethylethenylamine (6.48%), endo-9-anti-11-dichloro-syn-11 fluoro tricyclo [5.3.1.0] undecane (6.29%), 3-tert-Butoxycarbonylamino phenyl isonitrile (6.25%) and oleanolic acid (5.63%).

2.3.4 Phytopharmacology

Prashanth and Shiddamallayya (2014) [87] reported that *Ceropegia tuberosa* can be used for curing seminal debility and general debility. Prabakaran et al. (2014) [83] studied angiogenesis and antioxidant activity of *C. pusilla* tuber in vitro and in vivo. Anti-angiogenesis effect was studied by Chicken Egg Chorioallantoic Membrane (CAM) assay and antioxidant properties were analysed using 1, -diphenyl-2-picryl-hydrazyl free radical scavenging assay and cancer cell reducing power activity. *In vitro* anti-cancer activity of ethanolic extract of *in vitro* and in vivo tuber of *C. pusilla* has been studied by Kalimuthu et al. (2014) [45] and confirmed the *in vitro* antiproliferative property against HeLa line.

2.4 Coleus species

Chinese potato (*Solenostemon rotundifolius*) is an ancient Ayurvedic tuberous plant, belonging to the family Lamiaceae, considered as native of India. This is commonly known as hausa potato, sudan-potato, country potato. It is popularly known as poor man’s potato, because it fetches low price in market as compared to the other tuber crops. The flavonoids of Chinese potato have been reported to lower blood cholesterol (Abraham and Radhakrishnan, 2005) [2] as well as possess high antioxidant activity (Sandhya and Vijayalakshmi, 2005) [96]. Leaves also have reported medicinal uses such as treatment of nasal congestion, sore throat, coughs and also have antifungal, anti-inflammatory properties.

2.4.1 Ethno-Pharmacology

The Coleus leaves are bitter, acrid, appetizing, thermogenic, digestive, aromatic, carminative, anthelmintic, constipating, deodorant, expectorant, lithotriptic, diuretic and liver tonic and it has been used to treat congestive heart failure, painful urination, eczema etc. (Soni and Singhai, 2012) [105].

2.4.2 Phytoconstituents

Coleus species has been reported with presence of many bioactive compounds like alkaloids (forskolin and its derivatives), tannins and phenols with potential biological activities like increasing the insulin secretion, stimulating adenyl cyclise, inhibition of platelet aggregation, relaxation of the arteries etc. Various phytoconstituents in Coleus species are forskolin (diterpenoid), β-citronellol (3, 7- dimethyl oct-en-01), α-cedrene, γ- cadinene, citronellol (3, 7-dimethyl-6-octenial), labdane derivative (8-α, 13-β- dihydroxy labd 14-en-3-one) isolated from roots (Murugesan et al. 2012) [88].

2.4.3 Phytochemistry

Murugesan et al. (2012) [68] isolated 6 major components α-cedrene, β- cadinene, citronellol, two labdane derivatives and β-citronellol from the root extracts of *C. forskohlii*. *Coleus aromaticus* is rich source in presence of essential oils like ethyl salicylate, chavicol, carvacrol, thymol, eugenol and also contains caffeic acid, chlorogenic acid, coumaric acid and polyphenolic compounds (Dutta et al.1959) [29].

2.4.4 Phytopharmacology

Coleus tubers are rich sources of both enzymatic and non-enzymatic antioxidants, has been reported to exhibit antitumor and anti-mutagenic, antiepileptic, antioxidant, leishmania, urolithiasis, neuropharmacological, radioprotective effect, antimicrobial, antibacterial and antifungal properties. Forskohlin (diterpenoid) is an active compound in the tuberous roots of *Coleus forskohlii*, used as potential drug in respiratory disorders, hypertension, congestive heart failure, colic, eczema and painful urination because it helps in the production of compounds that relax the bronchial muscle. It has also traditional use as a vital medicine against asthma, angina, psoriasis and prevention of cancer metastasis. Medicinally important tuberous coleus species are *C. forskohli*, *C. amboinicus*, *C. blumei* and *C. malabaricus* and among these *C. forskohlii* is an important species yielding highest amount of forskolin, used for treating different diseases. Ethanolic extract of *Coleus aromaticus* is reported to have antiastagentic potency (Prasad et al. 2002) [86], nephroprotective activities, diuretic properties (Patel et al. 2010) [85]. Three components of rosmarinic acid, chlorogenic acid, caffeic acid rosmarinic acid have been extracted from *C. aromaticus* with water showed strong DPPH radical scavenging activity (Shyama and Vijayalaxmi, 2002) [104].

2.5 Costus species

*Costus* is a traditional medicinal plant, having the habit of erect or spreading stem, producing perennial rhizome and belongs to the family, Costaceae. There are different species in *Costus* genus, but *Costus speciosus* is mostly exploited for its medicinal use in Ayurveda. Different parts of *Costus* used as traditional medicine, especially rhizomes are better used...
for treatment of diabetes, abdominal pains, gall bladder pain, chest pains, liver problems and jaundice, fever, skin diseases, worm infection, leprosy, burning sensation and bronchitis (Sivarajan and Balachandran, 1994) [102].

2.5.1 Ethno-Pharmacology
Rhizomes are bitter in taste and exhibit anthelmintic, astringent, expectorant properties and also used in the treatment diabetes, herbal remedy for fever and treating boils. Leaves are used for treatment of scabies, stomach ailments and its paste applied to the fore head to bring down the fever.

2.5.2 Phytoconstituents
Saponins are reported in seeds, rhizomes and roots of Costus plant. Diosgenin, sitosterol, dioscin, gracillin, cycloartenol, cycloalaudanol, costunolide, eremanthin were extracted from roots (Duraipandiyan et al. 2012) [28]. Various compounds like 5α-stigmaster-3b-ol, sitosterol-β-D-glucoside, dioscin, prosapogenins A and B of dioscin, gracillin and quinines was isolated from rhizomes and roots of costus (Mahato et al. 1980) [60]. Five new compounds such as tetracycle 11-methyltridecanate, tetracycle 13-methylpentadecanate, 14-oxotricosanoic acid, 14-oxoheptacosanoic acid and 15-oxooctacosanoic acid isolated from rhizomes (Madan Gupta et al. 1981) [59].

2.5.3 Phytochemistry
Two sesquiterpenoid compounds were isolated (costunolide and eremanthin) from the Costus speciosus hexane extract and showed antibacterial and antifungal activities against Trichophyton mentagrophytes, T. simii, T. rubrum, T. rubrum, Epidermophyton floccosum, Scopulariopsis sp, Aspergillus niger, Curvularia lunata, Magnaporthe grisea (Duraipandiyan et al. 2012) [28]. Sheikh et al. (2013) [103] extracted the β-L-arabinopyranose methyl glycoside phytochemical with antidiabetic activity from C. puctus.

2.5.4 Phytopharmacology
Antifungal activity of costunolide and eremanthin, the phytochemical compounds, derived from the rhizome of C. speciosus acts against dermatophytes has been reported for the first time Duraipandiyan et al. (2012) [28]. Costunolide is a sesquiterpenes compound, possessing various immunological and biological actions, hypolipidemic effect, antimicrobial effect and antioxidant activities (Saraf, 2010) [99]. Costus speciosus contains several compounds such as tigogenin, dioscin, gracillin β-sitosterol glucoside and also reported an- cholinesterase activity, estrogenic activity, diuretic activity, anti-hyperglycaemic activity, anti-stress activity. Costus igneus (spiral flag herbaceous and starchy rhizomatous plant) is commonly referred as “insulin plant” grown in tropical regions of India. People in these areas are traditionally taking 2-3 leaves twice a day for controlling of diabetes (Sardessai et al. 2014) [98]. Akpan et al. (2012) [7] reported antimicrobial activity of Costus afer and also revealed the presence of tannins, flavonoids, saponins, cardiac glycosides terpenes and phlobatannins. Costus puctus commonly called as spiral ginger has been suggested as a magical cure for diabetes. Costus igneus ethanolic extract treated animals showed decrease in serum cholesterol & serum triglyceride, LDL along with increase in HDL as compared to diabetic control group (Palanivel et al., 2013) [82] and hepatoprotective activity against paracetamol induced liver damage (Chacko and Shastry, 2012) [17]. Ijioma et al. (2014) [40] reported the antinociceptive property of Costus afer stem juice and ethanol leaf extract in albino rats.

2.6 Giant Taro
Giant Taro (Alocasia macrorrhiza) is an indigenous belonging to the family Araceae. Giant taro is an important starchy crop with medicinal and nutritive values.

2.6.1 Ethno-Pharmacology
Traditionally different parts of giant taro are being used in treatment of inflammations and leaves extract is used for treatment of many diseases.

2.6.2 Phytoconstituents
The presence of glycosides, tannins, alkaloids, organic acids, steroids, triterpenes, saponins, flavonoids, gallic acid, ascorbic acid, glycosides, cyanogenetic glucosides and alocaisin etc. are reported in giant taro tubers Ellil (2014) [30].

2.6.3 Phytochemistry
Ellil (2014) [30] isolated and reported the ten compounds from A. macrorrhiza rhizomes those are, β-Sitosterol, epi-Betulinic acid, epi-ursolic acid, Oleanolic acid, 5α, 8α-epi-Dioxygenosta-6,22-dien-3β-ol, 5-Hydroxy-1H-indole-3-carboxylic acid methyl ester, α-monomalpin. 5-Hydroxy-1H-indole-3-(2-oxo-acetic acid), Alocasin B, Hyrtiosin B, β-sitosterol 3-O-β-D-glucoside and 1-O-β-D-glucopyranosyl-(2S,3R,4E,8Z)-2-{[(2R)-hydroxystadecanoyl]amido}-4,8-octadecadiene-1,3-diol respectively.

2.6.4 Phytopharmacology
Mubeen et al. (2012) [66] studied laxative and diuretic properties of Alocasia macrorrhiza on albino rats. Preclinical studies on rats proved the traditional diuretic activity of fresh leaves of Giant Taro (Acharya et al. 2014) [3]. The ethanolic leaf extract of A. macrorrhiza comprised of potential properties such as antioxidant, anti-inflammatory, antinoiceptive, antimicrobial, antidiarrheal, free radical scavenging and antiprotozoal (Mubeen et al. 2012) [66]. Rhizome extract from A. macrorrhiza showed moderate ABTS scavenging activity (66.47%) as compared to the standard antioxidant ascorbic acid (87.45%) (Ellil, 2014) [30].

2.7 Starchy Curcuma species
Curcuma genus contains about 80 species of rhizomatous herbs, mainly starchy Curcuma species includes Curcuma aeruginosa, C. amada, C. aromaticca, C. brog, C. zedoaria, C. caesia, C. harita, C. leucorrhiza, C. malabarica, C. rakthakanta, C. sylvatica (Angeli, 2012) [100]. Curcuma zedoaria is an herbaceous and starchy rhizomatous plant belonging to the family Zingiberaceae and grows up to one and half meter or even more.

2.7.1 Ethno-Pharmacology
Rhizomes of Curcuma aromaticca and C. xanthorrhiza are medicinally important species, widely used in India as a flavouring agent, tonic, carminative and used against snakebite (Chopra et al. 1941) [25]. Rural people used starchy curcuma species rhizomes for its digestive stimulant, rubefacient, expectorant, demulcent, diuretic, carminative and its root for treatment of cold, cough, fever, dyspepsia and infections.
2.7.2 Phytoconstituents
Starchy curcuma species contains diverse group of bioactive compounds such as curcuminoids including curcumin [1, 7-bis-(4-hydroxy-3-methoxyphenyl)-1, 6-heptadiene-3, 5-Dione], turmerin (a water-soluble peptide), essential oils (such as turmerones, atlantones and zingiberene), flavonoids, steroids, phenols, glycoside, alkaloids, tannins and saponins (Tholkappiyavathi et al. 2013) [100].

2.7.3 Phytochemistry
Curcumin [1, 7-bis-(4-hydroxy-3-methoxyphenyl)-1, 6-heptadiene-3, 5-Dione] is the important compound present in the rhizomes of Curcuma zedoaria (White turmeric), Curcuma manga (Mango ginger), Curcuma aromatica (Wild turmeric), Curcuma xanthorrhiza (Ubatamaaju) and non-curcumin species include C. amada, C. caesia, C. aeruginosa, C. amada, C. brog, C. malabarica and C. sylvatica (Lakshmi et al. 2011) [53].

2.7.4 Phytopharmacology
Essential oils extracted from Curcuma zedoaria tubers possess antibacterial properties and used in the treatment of colds and infections, carminative, digestive stimulant. Curuminoids are the novel compounds derived from C. zedoaria and have potential to fight against ovarian cancer cell lines (OVCA-3) (Syu et al. 1998) [108]. Lakshmi et al. (2011) [103] reported the effect of isocurcumenol derived from C. zedoaria as potential inhibitor of cell proliferation of human lung, leukemia, nasopharyngeal carcinoma and murine lymphoma cells and highlighted the potential of isocurcumenol as a good anti-tumour agent. The white turmeric having wide range of properties such as carminative, demulcent, rubefacient, expectorant, diuretic and stimulant is used in many treatments like halitosis dermatosis disorders, diarrhoea, coriza, rheumatism, stomach diseases, hepato protection etc. and showed anti-amoebic activity, antibacterial activity, antifungal, anti-arthritis activity, anti-oxidant activity, anti-inflammatory activity, anticancer activity, anti-hyperlipidemic activity, anti-hyperglycemic activity, anti-microbial and analgesic activity (Lakshmi et al. 2011) [53]. Curcuma aungustifolia is medicinally important starch producing species, showing activities like anticancerous and hepatoprotective. Angel (2012) [10] showed the higher antioxidant activity correlation with the presence of higher phenols in the rhizomes as compared to leaves of C. rakhakanta, C. aeruginosa, C. brog, C. malabarica and C. sylvatica. Pharmacological studies in mice showed that, curcumenol derived from Curcuma zedoaria was effective agent against the analgesic effect on neurogenic pain and it confirmed/justified the traditional use of this plant against many treatment of dolorous processes (Navarro et al. 2002) [72].

2.8 Swamp taro
Swamp taro (Cyrtosperma merkusii) is the important staple food on Pacific atoll islands (Murti et al. 2010) [69] and volcanic islands of Micronesia (Bradbury and Holloway, 1988). The plants are large and grow to a height of 15-20 feet and are grown in swamp areas and fresh water marshes.

2.8.1 Ethno-Pharmacology
Swamp taro tubers are consumed in the cooked form, preferred cryptosperma as coarse-textured, compared to taro, giving a gritty feeling in the mouth.

2.8.2 Phytoconstituents
It is important staple food in many islands of pacific, nevertheless few studies not been conducted on swamp taro nutritional composition. Engberger et al. (2008) [132] reported the presence of carotenoids (b- and a-carotene, β-cryptoxanthin, lutein, zeaxanthin, and lycopene) and minerals (including iron, zinc, and calcium) in swamp taro cultivars.

2.8.3 Phytochemistry
Engberger et al. (2003) [132] screened 13 Kosrae and Pohnpei Cyrtosperma cultivars for β-carotene and other carotenoids and cultivars were found to be rich in β-carotene and other carotenoids in range of 50 to 2040 mg of β-carotene/100g. They screened 34 cultivars of Cyrtosperma for carotenoids (b- and a-carotene, β-cryptoxanthin, lutein, zeaxanthin, and lycopene) and minerals (including iron, zinc, and calcium), and the range of β-carotene was found to be 50 to 4486mg/100g.

2.9 Tacca species
Tacca species have been used in traditional Chinese medicine and Thai herbal medicine for the treatment of various ailments. The plant is a tuberous marshy perennial, belonging to the family Dioscoreaceae and originated in Malaysia and the Pacific Islands (Purseglove, 1972) [91]. Tacca species find extensive use in ethnomedicine and ethnopharmacology and there are approximately 15 species such as T. aspera, T. leontopetaloides, T. integrifolia, T. involucrata (wild type), T. chantieri, T. paxiana, T. plantaginea, T. subflabellata, T. cheencher and T. chantiericeti.

2.9.1 Ethno-Pharmacology
Generally tubers are poisonous, but this can be removed by repeated soaking or washing or rinsing with water. Tubers are good sources of starch and medicinally important, containing steroidal saponins, ceryl alcohol and a bitter principle, Taccalin (Caddick et al., 2002) [16]. Tacca integrifolia tubers are used in leprosy, haemorrhagic diathesis and skin diseases. Tacca leontopetaloides fresh tubers are acrid, bitter, poisonous possess rubefacient property, used in treatment of dysentery, piles and diarrhoea (Jagtap and Satpute, 2015) [42]. In Nigeria, traditionally tubers of Tacca involucrata consumed as food, as well as roots and flowers are used by local people for treatment of snake bite, hepatitis, worm infections and as aphrodisiac.

2.9.2 Phytoconstituents
Tacca leontopetaloides tubers are good sources of diverse classes of secondary metabolites such as flavonoids (rutin, diosmin, saponin, chlorogenic acid and quercetin), phenols, alkaloids, tannins, coumarins, polysaccharides, glycosides, gums, terpenes, terpenoids, a bitter principle i.e. taccalin (Caddick et al. 2002) [16], steroids viz., taccalonolides, withanolides and their glucosides.

2.9.3 Phytochemistry
Tacca species gained the attention because of the presence of taccalonolides, withanolides etc. which are used as potential anticancer agents. Jagtap and Satpute (2015) [42] investigated the biochemical and ethnopharmacological significance of Tacca leontopetaloides and recorded the presence of flavonoids such as rutin, diosmin, saponin, chlorogenic acid and quercetin in tubers.
2.9.4 Phytopharmacology
Keardrit et al. (2010) [47] studied the analgesic, antipyretic and anti-inflammatory effects of T. chantrieri and confirmed the ethnomedical use. The disintegrate property of Taccia involucrate starch extracted from tubers was demonstrated by Oflofule (1998) [79].

2.10 Typhonium species

*Typhonium flagelliforme* generally referred as rodent plant in Malaysia. This plant is traditionally used by Malaysian people for treatment of cancer, because some of compounds from plant have been identified asanticancer.

2.10.1 Ethno-Pharmacology

Chinese and Filipinos have used flowers of *Typhonium flagelliforme* as anticoagulant and leaves as well as tubers exhibited antibacterial properties. It has been used in many traditional medicines to treat various problems particularly by the tribal people such as treatment for snake bite, gastric ulcer, head ache, asthma, swelling, vomiting, cough, skin eruptions, diarrhoea and dysentery (Ali et al. 2012) [9].

2.10.2 Phytoconstituents

Typhonium species are having sound sources of phytochemicals such as alkaloids, steroids, flavonoids and terpenoids in different plant parts.

2.10.3 Phytochemistry

Isovitexin, a flavonoid glycoside has been isolated from *Typhonium flagelliforme*, showed antioxidant activity.

2.10.4 Phytopharmacology

Mohan et al. (2008) [64] studied the antibacterial and antioxidant activities of *Typhonium flagelliforme* and reported to possess valuable anti-leukemic effects, anti-ulcerogeneric activity of aqueous leaf extract was also reported against ethanol-induced gastric mucosal injury in rats (Bardi et al. 2011) [12]. Pharmacological studies in rats showed that it has capacity to prevent hepatocarcinogenesis, anti-inflammatory, analgesic and anti-diarrheal activity activities of leaf extract of *Typhonium trilobatum* has been reported to support the ethnopharmacological uses of this plant. Alfarabi et al. (2015) [8] studied the anti-proliferation activity of lectin (tuber protein) from *Typhonium flagelliforme*, and referred it as a potential material for breast cancer treatments. Farida et al. (2012) isolated a flavonoid glycoside, isovitexin has antioxidant activity (DPPH free radical scavenging) with IC50 34.39μg/mL and cytotoxic activity using BSLT (LC50 15.84μg/mL). Analgesic, anti-inflammatory and anti-diarrheal activities of ethanolic leaf extract of *Typhonium trilobatum* has been studied by Ali et al. (2012) [9], that supports the ethnopharmacological uses of plant. Roy et al. (2012) [95] reported the potential wound healing activity of the different extract of *Typhonium trilobatum* in albino rats, among different extracts methanolic and ethyl acetate extract were found effective against wounding healing activity compared to chloroform extract in terms of breaking strength incision model.

2.11 Yam bean

Yam bean (*Pachyrhizus erosus*) commonly called as as jicama or Mexican yam bean or Mexican turnip, belongs to the family Leguminosae, native to North America. Total 6 species are grown for its edible tuberous tubers, but *P. erosus*, *P. tuberosus*, *P. ahipa* are important.

2.11.1 Ethno-Pharmacology

It Yam bean produces the edible tuberous roots. Seeds contains high protein and oil, used to treat worms and powdered seed is applied to treat the prickly heat during summer months especially in Java, skin eruptions and as fish poison (Perry and Metzger, 1980) [88] and know to contain wide number of phytochemicals such as flavonoids, rotenoids and phenylluranocoumarin.

2.11.2 Phytoconstituents

Even though yam bean seeds are rich sources of protein; they are not used for consumption because of presence of toxic rotenone.

2.11.3 Phytopharmacology

Presence of rotenone in the pods enables their use as potent insecticidal material (toxic to insect pests), showed potential antitumor activity and antifungal activity. Abid et al. (2006) [1] screened ethanol and chloroform extracts of *Pachyrhizus erosus* seeds for central nervous system (CNS) depressant activity and results showed that ethanol extract of the seeds (150 mg/kg, p.o) decreased locomotor activity, produced muscle relaxation and showed anti-anxiety and anti-aggressive activity. Widyarman et al. (2014) [110] studied effects of *Pachyrhizus erosus* juice in hampering blood glucose in rat models and conclude that there was no effect on hampering blood glucose levels.

2.12 Wild yam species


2.12.1 Ethno-Pharmacology

Tuber extract from wild yam species has been used for rheumatoid arthritis, stomach cramps, and pain from gallstones, menstrual cramps and discomfort, relieve labour pains, dysmenorrhea, intestinal colic, treat scabies, boils, and relieve the pain of childbirth. Dioscorea species possess profound therapeutic uses and consumed as food especially by the tribal people, apart from that these are mainly used for medicinal purposes to cure many dolorous processes.

2.12.2 Phytoconstituents

Sheikh et al. (2013) [103] screened different Dioscorea species for phytochemicals and confirmed the presence of wide classes of phytochemicals such as flavonoids, alkaloids, terpenoids, cardiac glycoside, steroids and saponins.

2.12.3 Phytochemistry

The Dioscorea hispida tuber peel is rich source of many phenolics compounds like caffeic acid, chlorogenic acid, phydroxybenzaldehyde and methylester of protocatechueic acid (methoxyprotocatechuate), these compounds are useful as dietary antioxidants to serve as a protective factor against oxidative cellular damage.

2.12.4 Phytopharmacology

Wild yam species possess various useful properties such as antisapmodic, aphrodisiac, purgative, anti-helminthic, deflatulent, rejuvenating, antioxidant activities, anti-inflammatory activity, anti-phlogistic effect and antibacterial...
activity. Catechin and other phenolic compounds present in *Dioscorea bulbifera* might be the responsible for the treatment of human cancer and flavonoids to the anti-tumor promoting activity. *D. villosa* has potential therapeutic uses such as relieving gas and pains of the bowels, labour pain during delivery (Moerman, 1998) [63]. Adeniran and Sonibare (2013) [64] reported on anti-helmintic activity of *D. bulbifera* in Nigeria and confirmed the ethnomedical uses of this plant by rural people, it also showed anti-hyperglycemic and anti-dyslipidemic activity (Ahmed et al., 2009) [6].

2.13 Winged bean

Winged beans (*Psophocarpus tetragonolobus*) are versatile edible legumes of tropical origin, belonging to the family, Fabaceae.

2.13.1 Ethno-pharmacology

It serves as root vegetable as well as it produces the edible leaves, shoot, pods, flowers and seeds. Winged beans are bountiful sources of minerals, fibre, vitamin C, vitamin A. Rural people are consuming the leaves and seed to cure skin sores such as boils and ulcers (Perry, 1980) [69].

2.13.2 Phytoconstituents

The most remarkable feature of winged bean tubers is that they are rich sources of protein, starch and B-complex vitamins (Thiamin, pyridoxine (vitamin B-6), niacin, and riboflavin). It is reported that 100g tuber provides 11.6 g of protein on comparison to 2.02 g/100 g and 1.36 g/100 g protein content in potato and cassava respectively. Immature pods of winged bean are commonly used as very low calorie vegetables that contains 49 calorie per 100g beans but mature beans comprise of high calorie content and high in protein content that equivalent to soy bean protein (Garcia and Palmar, 1980) [37].

2.13.3 Phytochemistry

Mohanty et al. (2013) [65] quantified the total polyphenols, flavonoids and tannins in *P. tetragonolobus* and revealed the highest percentage presence of kaempferol (1.07 - 790.5μg/g) and the lowest percentage of gallic acid (0.09 - 3.49μg/g) in the seeds.

2.13.4 Phytopharmacology

Latha et al. (2007) [54] reported the antimicrobial activities and toxicity of crude extract of the *Psophocarpus tetragonolobus* pods, suggested that pods are potential sources of novel antimicrobial compounds and high LC50 value signified that this plant is not toxic to human.

2.14 Blue Taro

Blue taro (*Xanthosoma violaceum*) is herbaceous perennial plant belonging to the family, Araceae. It is commonly cultivated for tubers as well as leaves in many tropics; it produces arrow shaped leaves from tubers. Nevertheless less information is available on phytoconstituents, phytochemistry and pharmacological studies.

2.14.1 Ethno-Pharmacology

Tubers are peeled and consumed after boiling as potatoes in different places of Kerala, India. Young leaves and petioles are eaten as spinach after chopping and cooked, eaten.

2.14.2 Phytoconstituents

Blue taro showed the high levels of phenolics compounds especially flavones, whose effectiveness as antioxidant agents (Rice-Evans et al. 1997) [94].

2.14.3 Phytochemistry

Picerno et al. (2003) [90] studied the polyphenol profile determination including total polyphenols, isolated the new flavone C-glycosides, apigenin 6-C-â-D-glucopyranosyl-8-C-â-D-apiofuranoside, as well as known flavone C-glycosides, including vitexin, isovitexin, isovitexin 4'-Orhamnopranoside, apigenin 6-C-[â-D-glucopyranosyl-(1f6)-â-D-glucopyranosyl] and apigenin 6,8-diC-â-D-glucopyranoside.

2.14.4 Phytopharmacology

The blue taro leaves were showed the antioxidant which has free radical scavenging properties due to the presence of the high phenolic content (Picerno et al. 2003) [90].

2.14.5 Conclusions

In conclusion, most of these minor and under-utilized tuber crops are very rich in nutrients, bioactive medicinal compounds and source for many food and industrial starches. These crops continue to play an important role in the tribal communities, especially as primary diet and medicine in their critical times. Their immense potential could be explored for therapeutic purpose and for as precursors for the synthesis of powerful and useful novel drugs. These crops being affordable to the poor people and hence the nutritional balance could be easily achieved. But minor tubers have remained underutilized due to lack of knowledge and awareness among people about their important role in human health. They have great potential and warrant future studies for the characterization of active compounds and their scientific validation as well as effective development of new promising leads in indigenous medicine sector.

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4. References


29. Dutta S. Essential oil of Coleus aromaticus of Indian origin, Indian Oil and Soap Journal. 1959; 25:120.


Dioscorea bulbifera: potent amylase and glucosidase inhibitors. Evidence-Based Complementary and Alternative Medicine, 2012; doi:10.1155/2012/92905.


