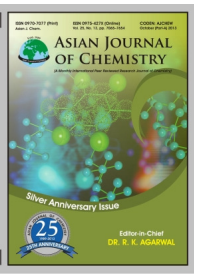
Asian Journal of Chemistry; Vol. 25, No. 17 (2013), 9425-9433

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2013.15405



REVIEW

Sauropus androgynus (L.) Merrill-A Potentially Nutritive Functional Leafy-Vegetable

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(*Received*: 1 March 2013; *Accepted*: 30 September 2013) AJC-14198

Sauropus androgynus (L.) Merrill [Family: Phyllanthaceae Martynov] is a popular leafy-vegetable in South and Southeast Asia and is notable for its high yields and palatability. The leaves and succulent young tips of the plant are normally eaten like tropical asparagus, raw in the form of salads or steamed or alternatively added to stir-fry, rice and egg dishes, soups or casseroles, and sometimes blanched to serve with chilli paste. The rich vitamin content of the leaves has led to its popular name, 'multivitamin green' and has also been recorded as a tropical vegetable by the United States Department of Agriculture. The flowers and the small purplish fruits of the plant are also reported to be eaten. The present paper attempts to review the health-impact of the nutritive factors and other phytometabolites biosynthesized by this functional leafy-vegetable, in addition to its ethnomedical claims.

Key Words: *Sauropus androgynus*, Nutritive potential, Ethnomedical potential, Chemical constitution.

INTRODUCTION

In the recent past, focus on food-plant research has increased many folds all over the world and experts are of the opinion that nutrition will become the primary treatment modality in the 21st century[1]. A significant amount of such studies to date has demonstrated the protective potentials of plant-based diets against a number of modern ailments. These include the leading clinical and public health issues in the developed countries and perhaps in the rest of the world too, namely, cardiovascular and neurodegenerative diseases, carcinogenesis and diabetes[2], which may be attributed predominantly to their antioxidant property. The multiple roles of wild traditional vegetables as both food and medicinal sources have been widely documented, including our publications[3-9]. Plants have developed survival and defence mechanisms in response to environmental stressors, pathogen-attack, competing-plants and herbivory[10]. This protection may be either mechanical or chemical in nature and the later is the result of the synthesis of the non-nutritive/antinutritive plant secondary metabolites. Over 200,000 such metabolites belonging to the flavonoid, tannin, saponin, alkaloid, cyanogenic glycoside, glycosinolate and terpene classes have been listed[11]. The dietary antioxidant micronutrients accumulated in fresh fruits and vegetables, particularly the leafy-vegetables, promote good-health by assisting in preventing cancer and high blood pressure, stimulating the immune system, improving drug metabolism and tissue regeneration. There are approximately 40 vitamins and minerals, which are considered essential for physical and mental development, immune system and metabolic processes. These are essentially acquired only through diet. It is estimated that up to 70 000 plant species are used in folk medicine and a vast majority of these species are found in the Asia-Pacific region[12]. One of the most popular functional leafy-vegetables of South and Southeast Asia is *Sauropus androgynus* (L.) Merrill[13], which has, in addition, gained popularity as a commodity of commerce[14]. The leaves and succulent young tips of the plant reportedly possess a pleasant taste, similar to fresh garden peas and slightly nutty. They are normally eaten like tropical asparagus, raw in the form of either salads or steamed, or alternatively added to stir-fry, rice and egg dishes, soups or casseroles. In Thailand, people cook the leaves with meat, coconut milk and other vegetables and prepare soup. The leaves are also blanched to serve with chilli paste. The leaves retain their dark green colour and firm texture on cooking and are served in restaurants as *sayor manis*. The flowers and the small purplish fruits of the plant too are reported to be eaten.

The data presented in this review were collected from published literatures as well as the data bases of Google, PubMed, Scopus, Science Direct, Scirus, FOODnetBase, Informa Healthcare and Google Scholar till 31st December 2012. Searches have been restricted to *Sauropus androgynus* in the Title, Abstracts and Keywords alone.

Systematics: *Sauropus androgynus* (L.) Merrill [Family: Phyllanthaceae Martynov; Euphorbiaceae sensu lato], Syn.: *Clutia androgyna* L., Mant. *Aalius androgyna* (L.) Kuntze; *A. retroversa* (Wight) Kuntze; *A. sumatrana* (Miquel) Kuntze; *Agyneia ovata* Poiret; *Andrachne ovata* Lamarck ex Poiret; *Phyllanthus strictus* Roxburgh; *Sauropus albicans* Blume; *S. albicans* var. *gardnerianus* (Wight) Müller Argoviensis; *S. albicans* var. *intermedius* Müller Argoviensis; *S. albicans* var. *zeylanicus* (Wight) Müller Argoviensis; *S. convexus* J. J. Smith; *S. gardnerianus* Wight; *S. indicus* Wight; *S. parviflorus* Pax and K. Hoffmann; *S. retroversus* Wight; *S. scandens* C.B. Robinson; *S. sumatranus* Miquel; *S. zeylanicus* Wight, is a functional leafy vegetable. The common names of this food plant among the traditional communities in various regions are briefed in Table-1.

The taxon is an erect, perennial shrub of 1-3 m tall, monoecious, glabrous throughout; branchlets angular when young, terete with age, slender, green. Leaves: Stipules lanceolate or linear-lanceolate, 1.5-3 mm; petiole 2-4 mm. Leaf blade ovate-lanceolate, oblong-lanceolate, or lanceolate, 3-10 cm long × 1.5-3.5 cm wide, submembranous or thinly papery, base cuneate, rounded, or truncate, apex acuminate; venation pinnate, lateral veins 5-7 pairs, elevated abaxially, flattened adaxially, reticulate veins obscure. Flowers: Inflorescence axillary, 1- or 2-flowered, or several male and female per cluster. Male flowers: pedicels slender, 5.0-7.5 mm; calyx shallowly disk-shaped, 5-12 mm in dia., shallowly 6-fid; sepals obovate; disk segments 6, opposite to sepals, incurved distally, covering anthers; stamens 3; filaments connate; anthers extrorse. Female flowers: usually solitary, axillary; pedicel 6–8 mm; calyx red, 6-lobed; sepals obovate or obovate-triangular, 5-6 mm × 3-5.5 mm, base attenuate into a short claw; disk absent; ovary depressed globose, 0.7 mm × 1.5 mm, 3-locular; styles 3, bifid. Fruiting pedicel 0.5-1.0 cm; persistent calyx red; capsule white, depressed globose or globose, 1.2 cm × 1.7 cm, thinly crustaceous. Seeds: black, triquetrous, 7 mm × 5 mm. Flowers: April–July; Fruits: July-December[13,15-20].

Distribution: *S. androgynus* grows rapidly in hot humid conditions but becomes relatively dormant in cooler environments. It appears to have originated from the hot humid lowland rainforest of Borneo and its present distribution spans from India and South China, through Indo-China and Malaysia to the Philippines, New Guinea and Solomon islands. It is more vigorous at lower altitudes but also grow up to an altitude of 1300 m in Malaysia and Indonesia. A species native to Indonesia, Malaysia, Singapore, Papua New Guinea, Philippines, China (Guangdong, Guangxi, Yunnan and Hainan), Bangladesh, Nepal, Myanmar, Cambodia, Thailand and Vietnam is said to be an introduced one in the Christmas and Cocos (Keeling) islands of Australia, Taiwan, Sri Lanka and the Hawaiian and Solomon islands, where the shrub is reported to be invasive and also cultivated[13-22]. In India, the shrub is reported to be found in Sikkim Himalayas, Khasi, Abor and Aka hills and in the Western Ghats of Kerala at altitudes of 600-1200 m[23-26]. It is said to have got introduced into Kerala from Malaysia in 1953. Reports of its occurrence in the peninsular India from the evergreen forests, clearings, scrub vegetation, roadsides and on waste grounds in Coimbatore, Madurai, Nilgiri, Tiruchirappalli, Tirunelveli and several other parts are available in literature[25-27]. Katuk is also reported to grow well in Florida and Puerto Rico and is claimed to have become one of the favourite salad greens[28,29]. The plant is usually propagated vegetatively, since the seeds have low germination power, but grows readily from cuttings. However, in Mindanao in the Philippines, the seeds sprout readily underneath plants in the hot, humid climate of that land[28]. Farmers in Malaysia are said to force the growth of stem tips by fertilization, irrigation and

TABLE-1
VERNACULAR NAMES OF *S. androgynus*

Language/Country	Local name (Ethnic group/Location)
English	Star gooseberry, sweet-leaf bush, sweet-leaf sauropus, sweet shoot, Chinese malunggay, Japanese Malungay, multivitamin green, multivitamin plant
Khmer (Cambodian)	Dom nghob, ngub
Chinese	Mani cai, Shou gong mu (Guangdong), Shu zai cai (Haina), yue nan cai (Guangxi)
Indonesia	Daun katuk (Sundanese), babing (Javanese), simani (Minangkabau)
Japanese	Ruridama-no-ki
Laos	Hvaan baanz
Malaysia	Katuk, sayur manis, asin-asin, cekur manis, chekup manis, cekok manis, pucuk manis, changkok manis (Peninsular), cangkok manis (Iban, Malay, Melanau)
Myanmar	Yo-ma-hin-yo
Philippines (Tagalog)	Binahian
Sri Lanka	Mella-dum-kola, Japan batu, Japanbatu kola
Spanish	Katuk
Thailand	Phak waan baan (General), pak waan (pak-wanban), kaan tong (Northern), ma yom paa (Prachuap Khiri Khan)
Vietnamese	Rau ngot, bu ngot (bo ngot), rau tuot, hum ngot, phac ot (Thai)
Indian States	–
Andaman & Nicobar Islands	Chakrmani
Assamese (Assam)	Bari sundari
Bengali (W. Bengal)	Chakurmani
Khasi (Meghalaya)	Dieng soh pit
Kannada (Karnataka)	Chakrani beru, Chinese soppu
Lepcha (Sikkim)	Sengtungrung
Malayalam (Kerala)	Malay cheera, elacheera (Muthuvan tribes of Idukki district)
Tamil (Tamil Nadu)	Thavasai murungai (thavasimurungai)

the use of shade cloth. Katuk is said to be disease and pest resistant, tolerates most soils and grows in sun or shade.

Nutritive potentials: *S. androgynus* is one of the most popular leafy-vegetables in South and Southeast Asia, best known for its high yields and palatability. It is a staple vegetable in Borneo, where it grows as an understory tree in the lowland rainforests. It is claimed to have a pleasant peanut-like taste when eaten raw whereas the cooked leaves taste excellent as spinach. The shoot tips are reported to be exported to Japan and possibly elsewhere as tropical asparagus. Vietnamese are said to cook it with crab meat, minced pork or dried shrimp to make soup while in Malaysia, it is commonly stir-fried with eggs and dried anchovies. In the Malaysian multi-racial cultures, any vegetable usually eaten raw in the form of salads is called an *ulam* and *cekur manis* is a notable *ulam* there. The villagers inhabiting the Don Sawan and Don Mor Thong forests of Bung Khong Long Non-Hunting area (located at Bung Khong Long district, Nong Khai province, in the north-eastern region of Thailand), are reported to eat the fresh tender or soft boiled leaves with sauce of chilli. Sometimes the leaves are said to be cooked together with ant's eggs as a curry for consumption[30].

In India, the Muthuvan tribes of Idukki district (Kerala) and the villagers of South Karnataka have been noticed to gather the wild tender leaves and shoots for food[31,32]. It has been reported that an analysis of the proximate composition of *S. androgynus* leaf has shown that its nutritive value is superior to other commonly consumed leafy-vegetables in India[33]. The literature reports of the proximate composition of the leaves are summarized in Table-2. The leaves are also found to contain the amino acids, lysine, methionine, tryptophan, phenylalanine, threonine, valine, leucine and isoleucine. Research has clearly demonstrated that the additive and synergistic combinations of scores of phytochemicals, which are either directly or indirectly involved in various redox processes, are responsible for the observed health benefits of indigenous vegetables. Similar to pharmaceutical agents, functional foods and nutraceuticals also possess physiological and molecular targets that modulate clinical end-points associated with chronic diseases[7]. Consequently, functional foods or their ingredients also tend to offer new economic opportunities.

A diet rich in plant foods can provide over 25,000 phytochemicals that cannot be supplied by a typical dietary pattern based on refined grains, added oils, sugar and salt[3]. Only traditional plant-based diets are the best sources of several of these phytoconstituents. Micronutrient deficiencies have evolved as a serious global problem, especially in areas where the diet lacks variety. A number of vitamins and minerals are considered essential for physical and mental development, immune system and various other metabolic processes. The essential roles of minerals in life processes are described in a number of publications[44] and the essential and trace mineral wealth of the leaves are documented in Table-3. Evidences have suggested that the plasma levels of vitamin C in large sections of the population are sub-optimal for the health protective effects. As it cannot be synthesized by human system, our body entirely depend upon dietary sources to meet the needs of this vitamin[3]. Apart from the well-known roles in vision, vitamin A is also important for several other physiological processes including, foetal development, cell growth and regulation of immune system[45]. According to the sixth report on the World Nutrition Situation[46], an estimated 163 million of children in developing countries manifest vitamin A deficiency, with a prevalence of 30 %. South central Asia, including India, is assessed to have the highest prevalence and along with central and west Africa, it has a prevalence of more than 40 %. 100 g of the edible katuk leaves have been determined, in a study, to provide as much as 10000 IU of this vitamin. The wealth of vitamins accumulated in the leaves (Table-4) has led to its popular name, 'multivitamin green' and has been recorded as a tropical vegetable by the United States Department of Agriculture.

While the nutritional significance of vegetables has long been recognized among the nutritionists and medicos, awareness among the general public of the health implications of diets rich in vegetables has emerged quite recently. Conventionally, food plays two major functions, *viz*., nutritional (providing individuals with the nutrients that are needed for the individual's metabolism) and sensory or hedonistic (through its taste, contribute to individual well-being). In the recent past, a new potential role of food has emerged: that of fulfilling a specific 'physiological' function. Foods that also satisfy this role are termed as 'functional' foods. They provide health effects that go well beyond the traditional nutritional benefits. The definition of a functional food generally require (i) that the base product is a food, (ii) that it contains or is fortified with an ingredient, a micronutrient or a naturally occurring chemical compound that possess a beneficial effect on health, well-being or disease prevention and (iii) that this effect goes beyond normal and adequate nutritional effects, (iv) that these effects have been demonstrated or are at least claimed and communicated to the consumers and (v) that these

TABLE-2
PROXIMATE COMPOSITION OF *S. androgynus* LEAVES REPORTED

Constituent	Composition								
	(Per cent)				(g/100 g EP)			(g/100 g FL)	
Moisture	85.4	88.32	79.4	–	79.8	89.9	88.46	78.19	88.0 g
Carbohydrate	–	5.36	6.9	11.6	6.9	54.5	3.86	–	–
Protein	5.25	4.84	7.6	6.8	7.6	15.8	4.19	8.31	3.4 g
Lipids	0.58	0.19	1.8	–	1.8	4.0	0.19	–	–
Fiber	1.75	1.11	1.9	–	1.9	30.6	1.20	–	–
Ash	5.25	0.17	2.0	–	2.0	12.9	1.38	–	–
Energy (kJ)	–	–	100.5	–	310.0	1327.0	169.11	–	117.0
Reference	**34**	**35**	**36**	**37**	**12, 38**	**39**	**40**	**41,42**	**32, 43**

EP = edible portion; FL = fresh leaf material; – = not recorded.

TABLE-3
MINERAL CONTENT OF *S. androgynus* LEAVES REPORTED

Minerals	Content						
	(ppm DL*)	(mg/100 g DL*)	(mg/100 g FL)	(mg/100 g EP)			
Magnesium	1587.00 ± 2.01	664.9 ± 38.1	–	0.5500	–	–	–
Potassium	269.15 ± 0.28	45.7 ±0 1.5	–	2.7700	2610.0	–	–
Sodium	–	306.3 ± 52.8	–	–	–	–	386.00
Calcium	206.82 ± 4.79	84.4 ± 08.1	313.0	2.7700	234.0	118.8	70.51
Phosphorus	81.43 ± 2.71	61.2 ± 03.5	-	0.6100	64.0	–	128.24
Iron	20.49 ± 0.89	212.5 ± 20.8	10.1	0 .0199	3.1	13.5	0.90
Zinc	11.02 ± 0.15	15.9 ± 0 6.6	–	–	–	–	0.90
Vanadium	7.41 ± 0.05	–	–	–	–	–	–
Manganese	4.76 ± 0.82	25.6 ± 05.8	–	–	–	–	–
Copper	1.54 ± 0.06	768.7 ± 11.4	–	–	–	–	0.29
Selenium	1.03 ± 0.02	–	–	–	–	–	–
Chromium	0.52 ± 0.08	–	–	–	–	–	–
Cobalt	0.06 ± 0.04	1.6 ± 00.1	–	–	–	–	–
Reference	**47**	**34**	**32,41**	**12**	**12, 36,38**	**39**	**40**

*Mean ± standard deviation of three determinations; DL = dried leaf material; EP = edible portion; FL=fresh leaf material; – = not recorded.

TABLE-4
VITAMIN CONTENT OF *S. androgynus* LEAVES REPORTED

Constituent	Content						
	(100 g EP)					(100 g FL)	
Vitamin A[a]	10000.00	9510.00	–	–	–	–	–
Vitamin B_1[b] (Thiamine)	0.23	0.48	–	–	–	–	–
Vitamin B_2[b] (Riboflavin)	0.15	0.32	–	–	–	–	–
Vitamin B_3[b] (Nicotinic acid)	–	2.60	–	–	–	–	–
Vitamin C[b] (Ascorbic acid)	136.00	247.00	56.10	190.83	–	22.00	314.30
Vitamin E[b] (α-tocopherol)	0.43	–	–	–	42.68	–	–
Provitamin A[a] (Retinol equivalent)	–	1889.00	–	–	–	–	–
Reference	**12,38**	**37,48**	**39**	**41,42**	**40,49**	**32**	**34**

[a] IU; [b]mg; – = not recorded.

effects can be expected to materialise when the food is consumed in dietary amounts.

It is fairly well established today that oxidative stress is at the core of the physiological processes and pathological mechanisms that maintain a healthy body and longevity[7]. Consequently, there has been an increased interest globally to identify dietary antioxidants that are pharmacologically potent for use in preventive and therapeutic medicine and also in the food industry. Since plants are known to synthesis a variety of antioxidants in response to oxidative stress, they represent a potential source of these pharmacologically active metabolites[4]. The antioxidant capacity of the aqueous ethanolic (70 %) leaf-extract has been confirmed by cyclic voltammetry[47]. Studies tend to support that natural antioxidants, endogenous to plants, can scavenge reactive species and current evidences strongly favour the significance of the ubiquitous carotenoids, tocopherols and polyphenols in preventing or in delaying the onset of a number of chronic human diseases. These compounds have been investigated to prevent oxidative damage to important biological membranes and to lipid-rich foods. As a result, they tend to delay, inhibit, or even prevent oxidative reactions by a variety of mechanisms[50].

Polyphenols are among the most widespread class of metabolites in nature and are derived from the C_6-C_3 phenyl-propanoid unit. Biosynthesis, according to this pathway, produces a wide array of phytophenolics, such as the phenolic acids, flavonoids, coumarins, stilbenes, proanthocyanidins, lignans and lignins[50]. The traditional Thai food, Kaeng phak waan baan, prepared from Phak wan ban (14.6), garlic (1.0), shallot (2.0), dried chilli (0.7), galangal (0.2), lemon grass (0.5), roasted dried fish (3.9), mungbean noodles (2.4), shrimp paste (0.7), salt (0.7 %) has been determined, in a study, to possess 48.42 ± 2.13 mg/100 g gallic acid equivalents(GAE) of phenolics[40]. A number of studies have conclusively established the rich polyphenolic content of the edible leaf (Table-5). Accumulating biochemical, clinical and epidemiological evidences support the chemoprotective potentials of these phenolic antioxidants against oxidative stress-mediated disorders. Furthermore, cellular damage, as a result of reactive oxygen, nitrogen and chlorine species, is believed to be a causative factor in the process of a multitude of chronic degenerative disorders, including ageing. Polyphenols have been shown to exhibit substantial protective effects on human carcinogenesis, cardiovascular and renal disorders, memory and cognitive function, age-related neurological dysfunctions such as Alzheimer's disease, ulcers and several other human ailments[4-8]. These actions of the phenolic antioxidants stem mainly from their free radical scavenging and metal chelating properties as well as their effects on cell signaling pathways and on gene expression.

Flavonoids are among the major dietary antioxidants that are proven to offer protection against a number of human ailments[3-8]. The daily intake normally exceeds the daily doses of all other classes of antioxidants, including the carotenoids, vitamins C and E, put together. About 80.5-95.7 % of the total leaf-phenolics have been determined to be flavonoids (Table-5).

TABLE-5
POLYPHENOLIC METABOLITES FROM *S. androgynus* LEAVES REPORTED

Tannins	Total phenolics			Flavonoids	Anthocyanins	Ref. No.
(mg/100 g)	(mg GAE/100 g)	(mg CE/100 g)	(mg CA/100 g)	(mg/100 g)	(mg/100 g)	
88.68	1150.95[a]	–	–	–	82.94[§]	34
–	1150.00[b]	–	–	1040.00[¶]	–	39
–	149.00[a]	–	–	143.00	–	41
–	138.01[a]	–	–	142.64	1.53[a]	42
–	–	–	576.00	–	–	51
–	1900.00[a]	–	–	1530.00	–	52
–	2300.00[b]		–	–	–	53
–	–	2930.00[c]	–	–	–	54
–	–	2840.00[d]	–	–	–	54
–	–	–	–	785.00	–	55

GAE = Gallic acid equivalent; CA = chlorogenic acid equivalent; CE = catechin equivalent; [§]cynidine-3-glucoside equivalent; [a]fresh leaf material; [b]dried leaf material; [¶]Rutin equivalent; [c]aqueous extract; [d]MeOH extract; – = not recorded.

Anthocyanins and tannins are the other classes of plant phenolics reported (Table-5). Three factors generally dictate the capacity of the flavonoids to act as effective antioxidants: (i) the metal-chelating potential that is strongly dependent on the relative arrangement of the phenolic and the carbonyl functional groups of the pyrone ring, (ii) the presence of H^+/e^- donating substituents that quench free radicals and (iii) the ability of the flavonoid ring systems to delocalize the unpaired electron, leading to the formation of a stable phenoxyl radical[4]. Flavonoids are known to act at the different development stages of malignant tumours by protecting DNA against oxidative damage, inactivating carcinogens, inhibiting the expression of the mutagenic genes and enzymes, which are responsible for activating procarcinogenic substances and activating the systems responsible for xenobiotic detoxification.

Carotenoids have attracted the interest of researchers from diverse fields including chemistry, biochemistry, biology, food science and technology, medicine, pharmacy and nutrition for more than a century. These fascinating lipophilic phytometabolites still continue to be intensely investigated. High intake or high serum levels of carotenoids have been recognized, today, as being associated with a lower risk of developing cardiovascular diseases, several types of cancer, cataracts and age-related macular degeneration based on a number of epidemiological studies[56]. As carotenoids are also pigments that cannot be synthesized by humans, they must be essentially derived through the diet and green leafy-vegetables appear to be the best dietary sources. The total carotenoids content of the edible leaves, recorded in literature, are summarized in Table-6. Among the ten *ulam* analyzed in a study by the International Islamic University of Malaysia, *cekur manis ulam* is said to have contained a substantially higher total carotenoids of 358.90 ± 21.43 µg/g dry sample[57] (DL).

Carotenoids are further classified into two groups, *viz*., the oxygen-containing xanthophylls and the purely hydrocarbon carotenes that lack oxygen. The dominant carotenoids in the human retina are the two xanthophylls: lutein (36 %) and zeaxanthin (18 %). They are also the only carotenoids detected in the human lens. They get selectively deposited from the blood into the macular, which is rich in cone receptors that permit us to have our maximal visual acuity. Though their biological function in the eye remains to be fully characterized, their roles in the human vision perception are significant. Their functions as antioxidants and to absorb the most energetic/damaging portion of visible light have also been proposed. Consumption of leafy-vegetables, such as *S. androgynus* is believed to have beneficial effects on improving vision-related abnormalities and prevention of eye diseases. Chronic vitamin A deficiency stands out as one of the most resistant nutritional problems in developing countries, despite (i) the symptoms are not difficult to identify, (ii) the etiology is well understood and (iii) treatments are at hand. In populations wherein vitamin A deficiency is a problem, fruit and vegetables consumption is promoted because of their provitamin A carotenoids contents. Hulshof *et al.*[48] have evaluated the provitamin A content to be the highest in the sweet shoot leaves (1889 retinol equivalents/RE in 100 g of the fresh edible portion) among the Indonesian foods that they have analyzed. The human body can convert these provitamin A carotenoids into the active form of vitamin A, retinol and its derivatives. In western societies, fruit and vegetable consumption is promoted because of the validated association between their increased consumption and the reduced risks of cancer and cardiovascular disease. Thus, they not only play a crucial role as precursors of vitamin A but are themselves powerful antioxidants and are linked with enhancement of the immune system as well as decreased risk of degenerative diseases such as cardio-vascular diseases, carcinogenesis, rheumatism, parkinson disease, infertility, age-related macular degeneration and cataract formation[3]. It may be inferred from Table-6 that *S. androgynus* leaves are a rich source of various carotenes and xanthophylls. Further, the young shoots have been determined to be richer in provitamin A than the mature ones (respectively, 8251 ± 804 and 7569 ± 1464 RE in 100 g of the dried portion).

Ethnomedical potentials: The relationship between human being and his environment has always influenced the cultures and traditions of every nation on earth. The utilization of plants as food and medicine is as old as the human civilization itself. Herbs have always been used by all cultures throughout history and have played a significant role in various ancient traditional systems of medication including the Chinese, Ayurvedic, Siddha, Unani and other indigenous traditional medical systems of the Asian countries, including the Jamu of Indonesia. Jamu refers to the traditional medicines of Indonesia and a Javanese jamu may consist of a single or a mixture of medicinal plants[59,60]. Medicinal plants continue to

TABLE-6
CAROTENOIDS CONTENT *S. androgynus* LEAVES REPORTED

Carotenoids	Content*					
	(µg/g DL)	(mg/100 g FL)	(mg/100 g DL)	(mg/100 g FL)	(µg/100 mL FL)	(µg/100 g EP)
Total carotenoids	358.90 ± 21.43	5.15 ± 0.07	–	–	19.40 ± 0.56	–
β-Carotene	96.40 ± 07.71	1.63 ± 0.02	–	13.35[§]	–	–
All-*trans*-α-carotene	–	–	–	–	–	1335 ± 878
All-*trans*-β-carotene	–	–	–	–	–	10010 ± 219
cis-β-carotene	–	–	–	–	–	1312 ± 349
Lutein	51.59 ± 01.11	–	110.6 ± 4.1	19.5 ± 0.8 29.91[§]	–	–
Neoxanthin	93.27 ± 04.54	–	–	–	–	–
Violaxanthin	117.63 ± 15.10	–	–	–	–	–
Zeaxanthin	–	–	48.1 ± 3.7	08.5 ± 0.8	–	–
Retinol equivalents (RE)	–	–	–	–	–	1889 ± 466[a] 7910 ± 104[b]
Reference	**57**	**42**	**56**	**56,58[§]**	**34**	**48**

*Mean ± standard deviation; DL = dried leaf material; EP = edible portion; FL = fresh leaf material; – = not recorded; [a]fresh edible portion; [b]dried edible portion; RE calculated as (1/6 all-*trans*-β-carotene) + (1/12 all-*trans*-α-carotene) +(1/12 *cis*-β-carotene).

play an important role in emerging and developing countries of Asia, in both preventive and curative treatments, despite advances in modern western medicine. The use of jamu is a part and parcel of Indonesian healthcare. The Javanese jamu is now used widely throughout the country and even in Malaysia and Brunei Darussalam. The jamus are available in the form of herbal powders, pills, tablets or capsules and constitute a part of the programme of national health in Indonesia as medicines, tonics, beverages, products of health and beauty care and so on. They also generate income to the people of many Asian countries, who earn their livelihood by selling materials collected from the forest, or by cultivating in their farms. The Javanese jamu is also manufactured in many big and modern industries in Java[59]. *S. androgynus* is a popular ingredient of a number of jamus of the Indonesians. Jamu made from the fresh leaves or roots are claimed to possess uterotonic activity and are commonly prescribed for the easy evacuation of retained placenta after child-birth. For this treatment, a dose of 40 g, in the form of an extracted juice is administered in 2 sub-doses at an interval of 10 min[12]. A more popular traditional use is to enhance and accelerate milk secretion by mothers[61]. The leaves of katuk are reported to be used as a medicine to relieve cough (antitussive) and to soothe the lungs, as a tonic and as a febrifuge to relieve internal fever[13]. Other literatures quote the use of *S. androgynus as a* lactation aid, an antipyretic, a colorant and also as a cure for hoarse voice[41,42]. However, its use as a galactagogue to stimulate lactation appears to be the most common claim in several parts of Asia[60-62]. The plant parts have also been linked to symptoms such as cholecystosis, fever, ophthalmia, rhinosis, sore, yaws and bladder in Duke's Phytochemical and Ethnobotanical Databases[63].

The traditional Thai herbal medical wisdom prescribes the oral administration of the well grated mixture of the root and stem of *S. androgynus*, root of *Clausena wallichii* Oliv. var. *guillauminii* J.F. Molino as a remedy for vertigo. As a treatment for measles and fever accompanied with rashes, it recommends the oral consumption of the triturated mixture of the root of *Acacia rugata* Merr., *Brassica rapa* Linn., root of *Myristica iners* Blume., *Knema corticosa* Lour., *Sauropus androgynus* Linn., *Oryza sativa* Linn., *Saccharum sinense* Roxb., which has been pulverized with potable water[64]. The low hill and high valley tribal people, *viz*., Karen, Lua, Htin and Khamu hill communities are said to cultivate the plant in household gardens, small orchards or plantations for their consumption[65]. In the Guangdong, Haina and Guangxi provinces of South China, the leaf has been found to be used to suppress productive cough with asthma, dry mouth and constipation. The flower is also utilized for haemoptysis management[66]. Since the Vietnamese traditional medicine has evolved under the shadows of Chinese traditional medicine, culture and rule, it is quite impossible to delineate traditional Vietnamese medicine or *Thuoc Nam* (Southern medicine) from traditional Chinese medicine or *Thuoc Bac* (Northern medicine). In Vietnam, an infusion of the root is reported to cause abortion and is frequently administered for the evacuation of placenta after child birth. The leaves, stem and root of bù ngót are claimed by the Central Highland and Mekong Delta villagers to be diuretic and also relieve fever and fungal infection of the tongue[67].

The Malay villagers in Kampung Mak Kemas, Terengganu of Malaysia have been noticed to consume orally the leaf-decoction as a measure to control hypertension and for treating nose ulceration[68,69]. The paste obtained after pounding with milk is also documented as a topical application for hair growth[68]. A mouth wash is said to be prepared from the juice of the fresh leaves and honey or made in the form of a paste and applied to the tongue and gums to cure thrush of the tongue in infants. The leaves are also reported to be used to treat erythema, measles and dysuria. A decoction of the root is claimed as a remedy for fever and for urinary bladder complaints like stricture of the bladder[70,71].

The *Irula, Mudugu* and *Kurumba* tribals, inhabiting the Attapadi hills of the Western Ghats of India are reported to consume the cooked leaves of *thavasimurungai* for the improvement of general health[72]. In certain other parts of Tamil Nadu and Kerala, the leafy-vegetable is frequently referred to as 'diabetic greens' as there is a general belief that it is useful for diabetic cure. Records of the use of the leaf-juice against eye ailments[73] and smoking of the dried leaves to cure tonsillitis[74] are available. Juice of the leaves of *chekkur manis*

pounded with the roots of pomegranate and the leaves of jasmine is also observed to be used against eye diseases[75]. A mixture of the root powder with lime juice and a glass of water is said to be orally administered thrice-a-day to control diarrhoea[76]. Consequently, it appears according to literature, that the uncooked *S. androgynus* juice has been widely advertised as a 'natural diet vegetable' possessing large amounts of nutrients and is capable of rapidly reducing weight, effective in controlling hypertension, gynecologic problems, hyperlipidemia, hyperuricemia, urolithiasis, gall stones and constipation during the years 1994 and 1995 in Taiwan[77].

Chemical constitution and their impact: Consequent to (i) the recognition of the value of traditional and indigenous pharmacopoeias, particularly of Asian origin, (ii) the incorporation of some ingredients derived from these sources into pharmaceuticals, (iii) the need to make health-care affordable for all and (iv) the widely prevalent perception that natural remedies are somehow safer and more efficacious than those that are pharmaceutically derived, herbalism has re-entered the mainstream worldwide during the latter part of the 20th century. For a variety of reasons, more individuals have started preferring to take personal control over their health, not only in the prevention of diseases but also to treat them, seemingly unaware of the potential problems associated with the use of herbs. Plant chemistry is extremely complex and an individual plant normally contains a plethora of chemicals, belonging to the different chemical classes, which work either independently or in concert.

Following the promotion of the uncooked *S. androgynus* juice as a 'natural diet vegetable', an outbreak of a poorly defined respiratory illness (characterized by stenosis and obstruction of bronchioles) has been observed during the late April 1995 in southern Taiwan[78] and during 2005 in Japan[79]. Based on clinical, radiological and pathological manifestations, followed by histopathological evidences from open lung biopsy of the affected patients, *Bronchiolitis obliterans* (BO) syndrome has been established. This is a less common pulmonary disease, characterized by inflammatory changes of the membranous and respiratory bronchioles. Subsequently, in late July 1995, patients with cardiopulmonary symptoms related to katuk consumption have also been identified in southern Taiwan and later *torsade de pointes* (an uncommon and distinctive form of polymorphic ventricular tachycardia, characterized by a gradual change in the amplitude and twisting of the QRS complexes around the isoelectric line). A paper has reported that in Taiwan a total of 278 patients have been affected with *Bronchiolitis obliterans* after its consumption[79]. Studies have then firmly established the association between consumption of the uncooked *S. androgynus* juice and the occurrence of *Bronchiolitis obliterans*[80]. A search in the databases for the term '*Sauropus androgynus*' has hit results varying from 64.95 % (Science Direct) to 80 % (PubMed) which relates to *Bronchiolitis obliterans*. An evaluation of the nutritional potential of *S. androgynus*, has claimed a considerable amount of the alkaloid papaverine, present to the extent of 580 mg/100 g of fresh leaf material (FL)[81]. However, laboratory testing of five samples of *S. androgynus* vegetable and two samples of its uncooked juice produced by vendors (which have been obtained from Northern, Central and Southern Taiwan by the Bureau of Food Sanitation) have been reported to have revealed no papaverine or any other suspicious chemical in the samples, except for the presence of unknown alkaloids[77]. Although Lai *et al.*[82] could not induce *Bronchiolitis obliterans* in rats by feeding or injecting juice from the plants or papaverine, Svetlecic *et al.*[83] were able to reproduce *Bronchiolitis obliterans* by their chronic intratracheal instillation. After the lapse of a week, infiltrations in the bronchial submucosa and lamina propria have been observed as well as lymphocytic clusters protruding into bronchial lumen. After the 28th day, the inflammatory phase had evolved to fibrosis of the bronchial walls and vasculature, characteristic of *Bronchiolitis obliterans*.

The incidence, however, has never been reported from other Asian countries, including Malaysia and Indonesia, where the traditionally cooked recipes are widely in vogue. In a survey of 12 Malaysian villages, the average weekly consumption of *S. androgynus* leaves, has been documented to be 156 g (range: 116-200 g)[84]. Another study has reported the presence of large amounts of all essential nutrients in the leaf and the different food preparations have been well accepted by a selected panel of eight judges in India[77]. Nevertheless, studies have clearly supported the association of *S. androgynus* ingestion with *Bronchiolitis obliterans* syndrome. The possibly significant risk factors are the consumption of larger total amounts of *S. androgynus*, uncooked preparation of *S. androgynus* food and ingestion of *S. androgynus* foods that are prepared by vendors (containing added supplements that could produce a synergistic effect and lead to the promotion of the development of *Bronchiolitis obliterans* syndrome)[77].

Phytoestrogens are phytometabolites that can have estrogen-like actions in humans and animals. The predominant phytoestrogens occurring in plants are the isoflavones, coumestans, flavonoids and lignans. Lignans constitute a large group of fiber-associated phenolic compounds, widely distributed in edible plants. Most of the ingested plant lignans from human foods are converted by the intestinal microbiota in the upper part of the large bowel to enterolignans, predominantly, enterolactone (ENL) and enterodiol. Enterolactone is believed to be the major biologically active lignin and studies involving administration of plant lignans, which are further metabolized to enterolactone, have been shown to inhibit or delay the growth of experimental mammary cancer. Though the mechanism of anticarcinogenic action is yet to be fully understood, there is intriguing evidence for enterolactone to be a modulator of estrogen signaling. These findings have generated interest in the use of plant lignans as components of functional foods that are effective as breast cancer risk reducers[85]. Glycosyllignans, *viz.*, (+)-isolariciresinol-3-α-O-β-glucopyranoside, (-)-isolariciresinol -3-α-O-β-glucopyranoside and (-)-isolariciresinol-3α-O-β-apiofuranosyl-(1→2)-O-β-glucopyranoside, (+)-syringaresinol di-O-β-glucopyranoside, have been isolated and characterized together with a megastigmane glucoside, (2R,6S,9S,7E)-trihydroxymegastigmane-4,7-dien-3-one-9-O-β-glucopyranoside (sauroposide) from the aerial part of *S. androgynus*[86]. The other isolates characterized in the study are the ionone glycoside, corchoionoside C and a purine nucleoside, guanosine. Three further nucleosides, *viz.* adenosine,

5'-deoxy-5'-methyl sulphinyladenosine and uridine have also been reported from *n*-butanol fraction of the ethanolic extract of the aerial parts[87].

Polyphenols, notably the ubiquitously distributed flavonoids, which contribute considerably to dietary antioxidants, have demonstrated a wide range of biochemical and pharmacological effects. They have been found to offer substantial protective effects on human carcinogenesis, cardiovascular and renal disorders, memory and cognitive function, age-related neurological dysfunctions such as Alzheimer's and Parkinson's diseases, ulcers and several other human ailments[6]. They are also capable of inhibiting enzymes such as prostaglandin synthase, lypoxygenase and cyclooxygenase that are closely related to tumorigenesis and induce detoxifying enzyme systems such as glutathione S-transferase. Studies have determined a total flavonoid content of 143 mg/100 g FL[41], consisting of kaempferol (138), quercetin (4.5), myricetin (< 0.00002), luteolin (< 0.006) and apigenin (< 0.03 mg/ 100 g FL). The major leaf-flavonol, kaempferol has been isolated as a mixture of two flavonoldiosides, 3-O-β-D-glucosyl-7-O-α-L-rhamnosyl-kaempferol and 3-O-β-D-glucosyl-(1→6)-β-D-glucosylkaempferol together with the bisdesmoside, 3-O-β-D-glucosyl-(1→6)-β-D-glucosyl-7-O-α-L-rhamnosylkaempferol, from the *n*-butanol fraction of the ethanolic extract of the aerial parts[87]. In an earlier study, certain kaempferol glycosides have been determined to exhibit significant antinociceptive response, in both noxious chemical and mechanical induction models, with concurrent hypoglycaemia. Hence, they appear to be a promising class of substances for inclusion in diabetic diet or as a prophylactic for vulnerable groups, particularly those suffering from painful diabetic neuropathy[88]. *p*-Hydroxybenzoic acid, ferulic acid, caffeic acid and vanilic acid are the phenolic acids that have been identified and reported[89].

Katuk leaves have been reported by Suprayogi *et al*.[90] to contain five C_{17}, C_{18} and C_{20} polyunsaturated fatty acids and their derivatives (which are significant as precursors in the biosynthesis of eicosanoids such as prostaglandin, prostacycline, thromboxane, lipoxines and leukotrienes), together with a 17-ketosteroid, 3-ethyl-3-hydroxy-5-α-androstran-17-one (possibly involved in the biosynthesis of steroid hormone such as progesterone, estradiol, testosteron and glucocorticoids) and 3,4-dimethyl-2-oxocyclopent-3-enylacetic acid (with likely participation in the citric acid cycle to produce ATP). From the 70 % ethanolic leaf extract of katuk, the following phytosterols (%): Stigmasterol (1.10), Stigmasta-5-en-3β-ol (0.69), Stigmasta-5,24-dien-3β-ol (0.64), together with the fatty acids and their esters (%): palmitic acid (5.30), octadecanoic acid (0.39), phenylmalonic acid, ethyl octadecatrienoate (9.36), methyl-11,14,17-eicosatrienoate (3.70), ethyltetradecanoate (0.69) have also been identified[91]. From the ether extract, benzoic, palmitic and 2-phenylmalonic acids, together with monomethyl succinate, terbutol, 2-propagytoxane, 3-(2-furanyl)-3-penten-2-one, 2-methoxy-6-methyl-4*H*-pyran-4-one have been detected[92]. The ethylacetate fraction has been reported to contain *cis*-2-methylcyclopentanol acetate; 2-pyrrolidinone and methyl pyroglutamate and *p*-dodecylphenol[92].

Conclusion

The potentially nutritive and healthy leafy-vegetable, *S. androgynus*, has earned its significance by demonstrating to the word that herbs too are double-edged swords like the other drugs in any system of medicine. Environmental stressors, including geographical and seasonal variations, soil conditions and a host of other factors may contribute considerably to the variations observed in the relative composition of the multitude of phytometabolites, biosynthesized in a vegetable/herb. It is wise for one to harness only the desired benefits by their discriminate use, as prescribed by the time tested traditions.

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