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Review Article

A Review on the Phytochemistry and Pharmacology of two *Hibiscus* Species with Spectacular Flower Colour Change: *H. tiliaceus* and *H. mutabilis*

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ABSTRACT

Among the *Hibiscus* species, *H. tiliaceus* and *H. mutabilis* display spectacular flower colour change. In this short review, the current knowledge on their phytochemistry and pharmacology is updated, and their botany and uses described. With phytosterols, triterpenes, triterpenoids, coumarins, amides, phenolic acids, and anthocyanins as chemical constituents, *H. tiliaceus* has pharmacological properties of antioxidant, antibacterial, tyrosinase inhibitory, cytotoxic, immunomodulatory, anti-inflammatory, analgesic, anti-diabetic, hypolipidemic, anti-tumour and anthelmintic activities. Chemical constituents of *H. mutabilis* include flavonoids, flavonol glycosides and anthocyanins with pharmacological properties of antioxidant, antibacterial, anti-inflammatory, analgesic, hepatoprotective, antiviral, anticancer, filaricidal, anti-allergy and anti-diabetic activities. Both *H. tiliaceus* and *H. mutabilis* have anti-inflammatory, analgesic and anti-diabetic activities in common. A quick literature search showed that at least five other species of *Hibiscus* share these pharmacological properties. Included in the search were extracts or compounds responsible and their mechanisms of action.

Keywords: *Hibiscus tiliaceus*; sea hibiscus; *Hibiscus mutabilis*; confederate rose; anti-inflammatory; analgesic.

INTRODUCTION

The genus *Hibiscus* (Malvaceae) comprises some 275 species in the tropics and sub-tropics of which 43 species are found in the Malesian region[1]. Documented in the *Flora of China*, 12 *Hibiscus* species are endemic and four are introduced in China[2]. Leaves of *Hibiscus* are simple, lobed, alternately or spirally arranged and have paired stipules[3]. Flowers are radially symmetrical with cup-shaped calyx, five petals joined at the base, style bearing many stamens, and stigma with five hairy lobes. Flowers of most *Hibiscus* species have a remarkable colour pattern with the inner base of petals forming a deep-coloured heart[4]. Another feature of *Hibiscus* is flower colour change which can be spectacular in some species. *Hibiscus* is widely cultivated as ornamental, food, and medicinal plants[1]. Leaves of some species are consumed as vegetable, and stem fibres are also used for pulp and paper. The mucilage is used as emollient and demulcent for abscesses, ulcers, cutaneous infections, swellings, boils and mumps. In South, Southeast and East Asia, the mucilage is believed to have a cooling effect, and is used for healing burns and scalds. The mucilage is also used as medication for treating cough, bronchitis, dysuria and menorrhagia. Midwives apply the mucilage to facilitate delivery of newborn. *Hibiscus* species have been reported to possess a wide range of pharmacological properties such as antioxidant, antibacterial, antihypertensive, anti-inflammatory, antipyretic, anti-cancer, anti-tumour, hepatoprotective, hypoglycaemic, antidiabetic, anticonvulsant, antihelminthic, anti-spermatogenic and antimutagenic activities[5,6]. In this short review, the major chemical constituents and pharmacological properties of *H. tiliaceus* and *H. mutabilis*, two *Hibiscus* species with spectacular flower colour change, are updated with some description of their botany and uses. Both species have been documented in a book on edible medicinal and non-medicinal plants[7]. A review of the pharmacology and secondary metabolites of ten *Hibiscus* species has included *H. tiliaceus* amongst them[8], and an overview on the phytochemistry and pharmacology of *H. mutabilis* has been documented[9]. Nevertheless, this review is still deemed appropriate and relevant, particularly the discussion on other *Hibiscus* species sharing similar pharmacological properties as *H. tiliaceus* and *H. mutabilis*, and their possible modes of action. There is a concurrent documentation in IJPPR where we reviewed the phytochemistry and pharmacology of *H. taiwanensis* and *H. schizopetalus*, two lesser-known *Hibiscus* species.

HIBISCUS TILIACEUS

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Botany and uses

Hibiscus tiliaceus L. (sea hibiscus) is a coastal plant of the tropics and sub-tropics[10]. Associated with mangroves, the species is a fast-growing tree that can grow up to 20 m tall. Leaves are heart-shaped. Flowers are bell-shaped with maroon-coloured heart and stigma. They are yellow in the morning, turning orange-red in the evening, and mauve the next morning (Figure 1). In Chinese folk medicine, the root of *H. tiliaceus* has been used as an antifebrile and emetic, and the leaf and bark have been used for the treatment of cough and bronchitis[11]. Flowers of *H. tiliaceus* are used to treat ear infections[12], and in birth control in countries of Asia and Africa[13]. In Indo-China, leaves are used as a laxative[1]. In the Philippines, the bark has been used for treating dysentery, and in Papua New Guinea, a decoction of leaves is taken for sore throat, pneumonia, cough, tuberculosis and diarrhoea.

Phytochemistry

Phenolics of *p*-coumaric acid, fumaric acid, kaempferol, kaempferol-3-*O*-D-galactoside, quercetin and quercetin-3-*O*-D-galactoside have been reported in fruits of *H. tiliaceus*[14]. In flowers of *H. tiliaceus*, cyanidin-3-glucoside is the major anthocyanin[4]. Other compounds identified in the flowers were saturated hydrocarbons of 15−34 carbons, methyl ester of fatty acids, α-tocopherol and phytosterols[15]. Recently, one anthocyanin (cyanidin 3-*O*-sambubioside) and four flavonols have been isolated from the flowers[16]. From the stem and bark, a new friedelane-type triterpene (27-oic-3-oxo-28-friedelanoic acid) and eight known triterpenoids have been isolated[17]. All the compounds were reported from *H. tiliaceus* for the first time. Out of eight triterpenoids isolated from leaves of *H. tiliaceus*, three with the rare nigrum skeleton were new[18]. Phytochemical analysis of *H. tiliaceus* led to the isolation of 10 compounds (ergosta-4,6,8, friedelin, germanicol, glutinol, lupeol, pachysandiol, β-sitosterol, stigmast-4,22-dien-3-one, stigmast-4-en-3-one, stigmasterol and 22-tetraen-3-one) from the stem and bark[19], and 14 compounds (azelaic acid, cleomiscosin C, daucosterol, friedelin, fumaric acid, hibiscolactone, kaempferol, quercetin, rutin, scopoletin, β-sitosterol, succinic acid, syriacusin A and vanillin) from the leaf and stem[20]. A new coumarin (hibiscusin) and a new amide (hibiscusamide) together with 11 known compounds (vanillic acid, syringic acid, *p*-hydroxybenzoic acid, *p*-hydroxybenzaldehyde, scopoletin, *N-trans*-feruloyltyramine, *N-cis*-feruloyltyramine, *β*-sitosterol, stigmasterol, *β*-sitostenone and stigmasta-4,22-dien-3-one) have been isolated from the stem wood of *H. tiliaceus*[21]. A continuing phytochemical study on the leaf and branch extracts of *H. tiliaceus* yielded two new tetracyclic triterpenoids (tiliacol A and tiliacol B) together with one known analog of tiliacol A[22]. Quantified using HPLC-DAD, the ethanol leaf extract of *H. tiliaceus* growing in Bangladesh yielded phenolic compounds of catechin, rutin, quercetin, and ellagic acid with contents of 99, 79, 69 and 59 mg/100 g, respectively[23].

Pharmacology

Antioxidant properties

Out of leaves and flowers of six *Hibiscus* species screened for total phenolic content (TPC) and free radical scavenging (FRS), extracts of *H. tiliaceus* ranked first with outstanding values[24,25]. TPC and FRS of *H. tiliaceus* leaves were 2.4 and 2.7 times those of *H. mutabilis*, which ranked second. Flowers were 4.9 and 5.6 times higher. Out of leaves of nine coastal plant species screened for antoxidant properties, TPC and FRS values of *H. tiliaceus* were the highest with young leaves having slightly higher values than mature leaves[26]. A similar trend was also observed for total flavonoid content and ferric reducing power. A comparison between the antioxidant properties of coastal and inland populations of *H. tiliaceus* did not show any distinct variation for both leaves and flowers[27]. With greater UV radiation in coastal areas, there was no evidence that coastal populations have stronger antioxidant properties. Flower extracts of *H. tiliaceus* have antioxidant effect protecting several strains of yeast cells against cytotoxicity of hydrogen peroxide (H_2O_2) and tert-butyl-hydroperoxide (TBHP),[14] and showed antigenotoxic and antimutagenic effects against oxidative DNA damage induced by H_2O_2 and TBHP in V79 cells[28]. The same group of researchers also reported that the flower methanol extract of *H. tiliaceus* had antidepressant-like influence on male Swiss albino mice without sedative side effect[29].

Antibacterial activity

The antibacterial activity of the methanol leaf extract of *H. tiliaceus* has been reported with minimum inhibitory doses of 1.0, 0.5 and 0.25 mg/disc against Gram-positive bacteria of *Bacillus cereus*, *Micrococcus luteus* and *Staphylococcus aureus*, respectively[25]. No inhibition was observed for Gram-negative bacteria of *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella choleraesuis*. The ethanol extract of dried *H. tiliaceus* leaves showed activity against *S. aureus*, *E. coli* and *Salmonella paratyphi* with diameters of inhibition zones of 9.0 mm and 12–15 mm at doses of 250 and 500 μg/disc, respectively[30].

Anti-tyrosinase activity

Leaf extracts of *H. tiliaceus* showed strong anti-tyrosinase activity. Out of 39 seashore plant species, and 36 edible and medicinal plant species found in Okinawa, Japan, leaves of *H. tiliaceus* had the highest tyrosinase inhibition[31,32]. Of four species of *Hibiscus* tested, leaves of *H. tiliaceus* had the strongest anti-tyrosinase activity (42%) followed leaves by *H. mutabilis* (25%)[25]. The value of *H. tiliaceus* was comparable to leaves of guava (41%) used as positive control.

Cytotoxic activity

Hibiscusamide, *N-trans*-feruloyltyramine and *N-cis*-feruloyltyramine isolated from the stem wood of *H. tiliaceus* had cytotoxic activity against P-388 and/or HT-29 cells with IC_{50} values < 4 g/ml[21]. Hibiscusamide was the most cytotoxic with IC_{50} values of 1.7 and 3.8 g/ml, respectively. Of the three tetracyclic triterpenoids isolated from the leaf and branch extracts of *H. tiliaceus*, the analog of tiliacol A showed potent cytotoxicity

against P388 and HeLa cells with IC_{50} values of 11.2 and 11.5 mmol/L, respectively[22].

Figure 1: Freshly open flower of *Hibiscus tiliaceus* is yellow in the morning (left) and mauve the next morning (right).

Figure 2: Flower of *Hibiscus mutabilis* is white (left) in the morning and pink (right) in the afternoon.

Immunomodulatory effects

Wistar rats administered orally with methanol leaf extract of *H. tiliaceus* at doses of 250 and 500 mg/kg/day for 28 days showed a significant increase in the production of circulating antibody titer in response to sheep red blood cells, a significant increase in primary and secondary hemagglutination antibody titer, and enhanced production of red blood cells, white blood cells and hemoglobin[33]. Evidently, oral administration of the extract has an immuno-modulatory effects in the Wistar rats.

Anti-inflammatory and analgesic effects

Successive methanol, petroleum ether, and chloroform leaf extracts of *H. tiliaceus* were tested for anti-inflammatory and analgesic effects in mice at oral doses of 250 and 500 mg/kg[34]. Results showed significant anti-inflammatory activity against carragennan-induced paw oedema after 2 and 3 h, and significantly inhibited acetic acid-induced abdominal writhing after 1 h. Ranking of effectiveness of extracts was methanol > chloroform > petroleum ether. The methanol wood extract of *H. tiliaceus* at 200 and 400 mg/kg was reported to have anti-inflammatory and analgesic effects in mice[35].

Anti-diabetic and hypolipidemic effects

In another study, the methanol flower extract of *H. tiliaceus* was evaluated for anti-diabetic and hypolipidemic effects using streptozotocin-induced diabetic Wistar rats orally administered with the extract at doses for 250 and 500 mg/kg for 21 days[36]. The extract showed significant anti-diabetic activity with improvement in body weight, reduction in serum cholesterol and triglycerides, and improvement in high density lipoprotein (HDL)-cholesterol level.

Anti-tumour activity

The anti-tumour activity of the aqueous root extract of *H. tiliaceus* has been reported[37]. Swiss albino mice bearing Dalton's ascitic lymphoma (DAL) were inoculated with the extract at a dose of 200 mg/kg/day for nine days, mean survival time and peritoneal cell counts were

Table 1: Hibiscus species with anti-inflammatory, analgesic and anti-diabetic properties.

Hibiscus species	Plant part	Extract/compound	Activity	Reference
H. tiliaceus	Leaf	Successive	Anti-inflammatory, analgesic	34
	Wood	Methanol	Anti-inflammatory, analgesic	35
	Flower	Methanol	Anti-diabetic, hypolipidemic	36
H. mutabilis	Leaf	Ethanol	Anti-inflammatory	47
	Bark	Successive	Analgesic	48
	Leaf	Methanol	Anti-diabetic	53,54
H. cannabinus	Leaf	Successive	Anti-inflammatory, analgesic	55
	Leaf	Methanol	Anti-diabetic	56
H. rosa-sinensis	Leaf	Methanol	Anti-inflammatory, analgesic	57
	Leaf, flower	Ethanol	Anti-inflammatory	58
	Leaf	Aqueous, ethanol	Analgesic	59
	Flower	Ethanol	Anti-inflammatory, analgesic	60
	Flower	Aqueous	Hypoglycaemic, hypolipidemic	61
	Flower	Ethanol	Anti-diabetic	62
H. sabdariffa	Leaf	Methanol	Anti-inflammatory	63
	Seed	Petroleum ether	Anti-inflammatory, analgesic	64
	Calyx	D, DS	Anti-inflammatory	65
	Calyx	Ethanol	Hypolipidemic	66
	Calyx	Methanol	Hypoglycaemic, hypolipidemic	67
H. schizopetalus	Leaf	Successive	Anti-inflammatory	68
	Leaf, flower	Methanol	Analgesic	69
	Leaf, flower	Methanol	Hypoglycaemic, hypolipidemic	70
H. taiwanensis	Stem	Aqueous	Anti-inflammatory, analgesic	71
	Stem	Acetone	Hypoglycaemic	72–74
	Stem	SA	Hypoglycaemic	75

D = Delphinidin, DS = Delphinidin 3-sambubioside, SA = syringaldehyde

enhanced, and tumour cell growth was found to be inhibited. The results indicated that the extract treated groups were able to reverse their haematological parameters altered by DAL cells within 14 days. In the Traditional Chinese Medicines (TCM) database, *H. tiliaceus* has been recorded as an anti-tumour agent, which has been validated by western medicine in the Comprehensive Medicinal Chemistry (CMC) database[38].

Anthelmintic activity

The anthelmintic activity of leaf and wood extracts of *H. tiliaceus* has been reported[39]. Tested against *Pheretima posthuma* based on time of paralysis and time of death using 10−40 mg/ml of extracts, good activity was shown by the ethyl acetate leaf extract (28−46 and 45−74 min) and petroleum ether wood extract (29−45 and 47−78 min), respectively.

HIBISCUS MUTABILIS

Botany and uses

Hibiscus mutabilis L. (confederate rose) is an inland woody shrub (1.5−4.0 m tall) that is native to China and widely cultivated in Southeast Asia[1]. Leaves are broadly ovate with mostly five triangular lobes. Although *H. mutabilis* produces large and beautiful flowers, its constraint as ornamental plants is the frequent and unsightly infestation of whiteflies.

Flower colour change in *H. mutabilis* is most spectacular. Flowers are white in the morning, pink in the afternoon, and red in the evening (Figure 2). Temperature may be an important factor affecting the rate of colour change as white flowers kept in the refrigerator remain white until they are taken out to warm, whereupon they slowly turn pink[3]. Leaves and flowers are emollient and cooling, and are used to treat swellings and skin infections[1]. Midwives use mucilage from flowers and leaves to facilitate delivery during labour.

Phytochemistry

Phytochemical analyses of *H. mutabilis* are focused on the flowers, which are white in the morning, pink during noon and red in the evening. Analysis of petals showed the presence of flavonol glycosides[40]. Anthocyanins, absent in the morning, were found during noon and in the evening. They were cyanidin 3,5-diglucoside and cyanidin 3-rutinoside-5-glucoside. Studies have shown that the total anthocyanin content in the evening was 3-fold greater than that at noon. Flavonols of noon and evening flowers were identical to those of morning flowers. Since there was no reduction in flavonol content, it was suggested that the anthocyanins were synthesized independently. The main pigments of white and red flowers of *H. mutabilis* were due to quercetin 3-sambubioside and cyanidin 3-sambubioside, respectively[4]. These compounds were previously identified as quercetin 3,5-diglucoside and cyanidin 3,5-diglucoside. As the glycoside compounds were identical, there is a possibility that anthocyanins are formed through direct conversion of flavonol glycosides. A related study reported that colour change of *H. mutabilis* flowers from white to red is due to the accumulation of cyanidin-3-sambubioside[41]. At the intial and rapid phase of pigment accumulation, phenylalanine ammonia-lyase (PAL) activity in the intact petals increases rapidly to seven

times its initial level and then decreases when the flower senesces. In excised petals, the PAL inhibitor (L-α-aminooxy-β-phenylpropionic acid) suppresses pigment formation. Findings showed that the rapid accumulation of cyanidin in the petals was due to *de novo* synthesis *via* the shikimate and phenylpropanoid pathways, and ruled out the synthesis from precursors such as hydroxycinnamic acid conjugates or colourless flavonoids. In addition to cyanidin 3-xylosylglucoside and cyanidin 3-glucoside, the red flowers of *H. mutabilis* contained quercetin 3-sambubioside, isoquercitrin, hyperin, guaijaverin and kaempferol glycosides[42]. Bioassay-directed fractionation of the methanol extract of petals of *H. mutabilis* led to the isolation of mutabiloside, a new flavonol triglycoside, together with four known flavonols, which included quercetin and hyperoside[43]. From the ethanol stem extract of *H. mutabilis*, a new flavanone glycoside has been isolated[44]. Recently, steppogenin, genistein, salicylic acid, rutin, potengriffioside A, kaempferol 3-*O*-rutinoside and emodin were identified from the ethanol leaf extract of *H. mutabilis*[45]. The first two compounds are new to the species.

Pharmacology

Antioxidant properties

Out of the six *Hibiscus* species screened for antioxidant properties of total phenolic content and free radical scavenging values of *H. mutabilis* leaves and flowers ranked second and fourth, respectively[24]. Their values were 2.4, 2.7, 4.9 and 5.7 times lower than leaves and flowers of *H. tiliaceus*. Under laboratory conditions, flower colour change of *H. mutabilis* was slower than that of flowers under outdoor conditions. Red flowers had higher values than pink and white flowers. Based on total anthocynanin content, red flowers were 2.7 times that of pink flowers and 7.7 times that of white flowers. Overall ranking of the antioxidant properties of *H. mutabilis* flowers was red > pink > white.

Antibacterial activity

The methanol and ethyl acetate extracts of *H. mutabilis* have been reported to possess antibacterial activity[46]. At 8.0 mg/disc, the extracts inhibited *Bacillus subtilis*, *Klebsiella pneumoniae*, *Proteus vulgaris*, *Salmonella typhi*, *E. coli* and *S. aureus* with zones of inhibition ranging from 10−15 mm.

Anti-inflammatory effects

Recently, the anti-inflammatory effects of leaves of *H. mutabilis* have been reported[47]. Results showed that the ethanol leaf extract had no apparent effect on the viability of RAW264.7 cells but TNF-α, IL-6 and NO release in LPS-induced RAW264.7 cells and in the serum of experimental arthritic rat were significantly inhibited.

Analgesic activity

The analgesic activity of petroleum ether, ethyl acetate, and methanol bark extract of *H. mutabilis* was evaluated in mice using the hot plate method and acetic acid-induced writhing test[48]. All extracts showed analgesic activity at 50 and 100 mg/kg respectively. In the hot plate method, the petroleum ether extract showed the highest increase in reaction time. The methanol extract showed more inhibitory effect on writhing induced by acetic acid as compared to other extracts.

Hepatoprotective effect

The hepatoprotective effect of ethanol leaf, stem, and flower extracts of *H. mutabilis* against CCl_4-induced hepatic injury in rats has been reported[49]. Administration of CCl_4 significantly increased the release of alanine transaminases, aspartate transaminases and alkaline phosphatase. Results showed that 200 mg/kg of the extracts administered to the rats for seven days significantly modulated these enzymes in blood serum to normal values. Research by the same group of scientists showed that the ethanol leaf and flower extracts of *H. mutabilis* possessed antimitotic activity[50]. Roots of *Allium cepa* incubated with the extracts for three days were shorter in root length and fewer in number. The antimitotic activity of the extracts was comparable with paracetamol as the standard drug used.

Antiviral and anticancer activities

A hexameric lectin isolated from *H. mutabilis* seeds showed potent inhibition of HIV-1 reverse transcriptase with IC_{50} value of 0.2 μM[51]. The anti-proliferative activity of the lectin towards HepG2 (40% inhibition) and MCF-7 (50% inhibition) human cancer cells was however weak at 100 μM.

Filaricidal activity

Recently, the methanol leaf extract of *H. mutabilis* and the isolated ferulic acid were reported to display significant filaricidal activity against microfilaria and adult worms of *Setaria cervi*, a bovine filarial parasite[52]. Extreme cellular disturbance characterized by chromatin condensation, *in situ* DNA fragmentation and nucleosomal DNA laddering was observed in ferulic acid-treated adult worms.

Anti-allergy effects

Among the flavonol derivatives isolated from the methanol extract of flower petals of *H. mutabilis*, mutabiloside showed significant allergy-preventive effects using an *in vivo* assay that monitors the decrease in blood flow at the tail vein of mice subjected to egg white lysozyme sensitization[43].

Anti-diabetic properties

Ferulic acid and caffeic acid identified from the ethyl acetate fraction of the methanol leaf extract of *H. mutabilis* using RP-HPLC-DAD were found to inhibit α-glucosidase, suggesting they possess anti-diabetic properties[53]. Ferulic acid purified from the methanol leaf extract of *H. mutabilis* has been reported to inhibit lipid induced insulin resistance in skeletal muscle cells[54]. In high fat diet diabetic rats, ferulic acid (0.6 mg/kg) was orally administered at alternative days for 15 days, reduced blood glucose level and enhanced lipid uptake activity of adipocytes isolated from adipose tissue. As skeletal muscle and adipose tissues are known to be important insulin target sites the study concluded that ferulic acid showed promise as a good therapeutic choice for treatment of type-2 diabetes.

DISCUSSION

Although *Hibiscus* species are endowed with diverse chemical compounds that have different pharmacological properties, both *H. tiliaceus* and *H. mutabilis* have anti-inflammatory, analgesic and anti-diabetic activities in common (Table 1). A quick literature search revealed that at least five other *Hibiscus* species (*H. cannabinus*, *H. rosa-sinensis*, *H. sabdariffa*, *H. schizopetalus* and *H. taiwanensis*) share similar pharmacological activities. Only a few studies were conducted on the modes of action of extracts or compounds responsible. Polyphenols extracted from *H. sabdariffa* has the ability to prevent inflammation by impairing cyclooxygenase-2 (COX-2) induction, and by down-regulating Jun N-terminal kinase (JNK) and p38 mitogen-activated protein kinase[76]. In lipopolysaccharide (LPS)-stimulated mouse macrophages, the aqueous stem extract of *H. taiwanensis* inhibited nitric oxide (NO), tumor necrosis factor and prostaglandin E2 production[71]. The extract blocked protein expression of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2), and elevated heme oxygenase-1 (HO-1). In the animal test, the extract decreased paw oedema and increased antioxidant enzymes activities in the paw tissue. The extract decreased iNOS and COX-2, and increased HO-1 expressions in the oedema paw. Recently, the antiinflammatory activity and molecular mechanisms of delphinidin 3-sambubioside (DS) and delphinidin (D) extracted from calyces of *H. sabdariffa* have been investigated[65]. The cell model, DS and D reduced the levels of inflammatory mediators induced by LPS, and downregulated NF-kB pathway and MEK1/2-ERK1/2 signaling. In the animal model, DS and D reduced the production of IL-6, MCP-1 and TNF-α and ameliorated mouse paw oedema induced by LPS. Syringaldehyde (SA) isolated from stems of *H. taiwanensis* has the ability to lower hyperglycemia[75]. The compound significantly decreased post-prandial plasma glucose in rats, while plasma insulin was not modified. Administration of SA for 3 days in streptozotocin-induced diabetic rats resulted in marked reduction of PEPCK expression in the liver and increased expression of GLUT 4 in the skeletal muscle, suggesting that SA can increase glucose uptake and lower hyperglycemia in diabetic rats. Many herbs used as Traditional Chinese Medicine (TCM) have also shown to inhibit inflammation, pain and swelling in different organs of the human body[77,78], and to prevent and treat diabetes with clinical trials[79]. It would be interesting to compare the mechanisms of action of *Hibiscus* species with those of TCM herbs.

CONCLUSION

Both *H. tiliaceus* and *H. mutabilis* have anti-inflammatory, analgesic and anti-diabetic activities in common. A quick literature search showed that at least five other *Hibiscus* species (*H. cannabinus*, *H. rosa-sinensis*, *H. sabdariffa*, *H. schizopetalus* and *H. taiwanensis*) share similar pharmacological properties. Of the two species reviewed, *H. tiliaceus* is the most studied with publications by scientists from at least six countries. Publications on *H. mutabilis* came from at least four countries with several recent papers on its pharmacological properties. The current isolation of new and known compounds from *Hibiscus* species has been mostly associated with their medicinal values. There is hardly any work done relating phytochemistry to their biological and ecological functions. It is time that the biologists and ecologists work with the natural product chemists and pharmacologists on these ornamental, food and medicinal plants.

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