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# Ethnomedicinal, phytochemical and pharmacological profile of genus *Abelmoschus*

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## Ethnomedicinal, phytochemical and pharmacological profile of genus *Abelmoschus*

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### Abstract

*Abelmoschus* is a genus of about fifteen species of flowering plants in the mallow family, Malvaceae, native to tropical Africa, Asia and northern Australia. It was formerly included within *Hibiscus*, but is now classified as a distinct genus. The genus comprises annual and perennial herbaceous plants, growing to 2 m tall. The leaves are 10-40 cm long and broad, palmately lobed with 3-7 lobes, the lobes are very variable in depth, from barely lobed, to cut almost to the base of the leaf. The flowers are 4-8 cm diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal. The fruit is a capsule, 5-20 cm long, containing numerous seeds. Members of this genus have been reported to exhibit diverse medicinal properties ranging from antidiabetic, antimicrobial, anticancer, analgesic, antioxidant and antiplasmodial activities. Though there have been reports that some members of this genus exhibit toxic effect, extracts from the leaves, fruits and roots have shown no harmful effects on living cells. Reported compounds isolated from some species of the genus *Abelmoschus* contain primarane skeleton which could be responsible for their similar biologic activity as well as can be explored as a basis for their classification.

**Keywords:** *Abelmoschus*; Phytochemistry; Pharmacology

### Introduction

Plants of the genus *Abelmoschus* belong to the family of flowering plants called *Malvaceae*; this genus, also known as *okra* is composed of numerous species of flowering plants in the mallow family and they are native to tropical and sub-tropical areas (Charrier, 1984). Two are widely cultivated: *A. esculentus*, found throughout the tropics, and *A. caillei*, which is cultivated extensively in Africa (Hamon, 1987; Hamon and Van Slotten, 1989). Interest in the crop is due principally to the high protein and mineral salt content of the pods, making

okra a very good vegetable. Studies have shown that the daily consumption of 100 grams of okra provides 20% of the calcium, 15% of the iron, and 50% of the vitamin C of human dietary requirements (Grubben, 1977).

There are four known domesticated species of the genus *Abelmoschus*; among these, *A. esculentus* (common okra) is most widely cultivated in south and east Asia, Africa, and the southern USA. In the humid zone of west and central Africa, *A. caillei* (West African okra) with a longer production cycle, is also cultivated (Siemonsma, 1982). Plants of *A. manihot* sometimes fail to flower and this species is extensively cultivated for leaves in Papua New Guinea (Hamon and Sloten, 1995), Solomon Islands and other South Pacific Islands (Keatinge, 2009). The fourth domesticated species, namely, *A. moschatus*, is cultivated for its seed, which is used for ambrette in India and several animism practices in south Togo and Benin (Hamon and Sloten, 1995).

### Botany and Taxonomy

The genus comprises annual and perennial herbaceous plants, growing to 2 m tall. The leaves are 10–40 cm long and broad, palmately lobed with 3–7 lobes, the lobes are very variable in depth, from barely lobed, to cut almost to the base of the leaf. The flowers are 4–8 cm diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal. The fruit is a capsule, 5–20 cm long, containing numerous seeds (Verma *et al.*, 1993; Agharkar, 1991).

*Abelmoschus* was originally classified as a section under the genus *Hibiscus* in the family Malvaceae (Linnaeus, 1753) but was subsequently proposed to be raised to the rank of distinct genus by Medikus, 1787. The wider use of *Abelmoschus* was subsequently accepted in the taxonomic and contemporary literature (Hochreutiner, 1924). About 50 species have been described by taxonomists in the genus *Abelmoschus*. The taxonomical revision undertaken by van Borssum Waalkes (1966) and its continuation by Bates (1968) constitutes the most fully documented studies of the genus *Abelmoschus*. Taking classification of van Borssum Waalkes as the starting point, an up-to-date classification was adopted at the International Okra Workshop held at National Bureau of Plant Genetic Resources (NBPGR) in 1990 (IBPGR 1991).

### Geographical distribution and ecology

The species *A. moschatus* has a wide geographical distribution: India, southern China, Indochina, Indonesia, and southwest Pacific islands, Papua New Guinea, northern Australia, Central and West Africa. Within the species two ecologically adapted forms are distinguished: the sub-species *biakensis* occurs only in Papua New Guinea near the sea; the subspecies *tuberosus*, or *A. rugosus* according to Bates, is particularly resistant to drought and fire due to its tuberous roots (Chevalier, 1940).

The species *A. manihot* subsp. *manihot* is cultivated mainly in the far East, but also in the Indian sub-continent and northern Australia. It is less frequently found in America and tropical Africa. On the latter continent, Chevalier (1940) described the variety *zenkeri* in Ca-

meroon and the variety *caillei* in West Africa. The latter has also been observed in Zaire (Hahuman, 1963).

The species *A. manihot* subsp. *tetraphyllus* comprises two wild forms differentiated by van Borssum-Waalkes (1966) on the basis of their ecological adaptation. The first, var. *tetraphyllus*, grows at low altitudes between 0 and 400 m, in the regions with a marked dry season of Indonesia, the Philippines, Papua New Guinea and New Ireland. The second, var. *punens*, grows at altitudes between 400 and 1600 m in Indonesia and the Philippines.

The species *A. esculentus* is cultivated as a vegetable in most tropical and subtropical regions of Africa, India and America. In West Africa, Siemonsma (1982b) has clearly demonstrated that the species has preference for the Sudano-Sahellian zone. However, *A. esculentus* is also found in forest regions in smaller quantities. This Guinean bioclimatic zone, Siemonsma (1982a,b) has given prominence to a new cultivated species provisionally called "Guinean" okra, which can be found in the forest regions of Ghana, Guinea, Ivory Coast, Liberia and Nigeria.

The wild species *A. tuberculatus*, related to *A. esculentus*, is endemic to the medium altitude hilly areas of Uttar Pradesh near Saharanpur in northern India and in the regions of Ajmer and Indore in western India. The wild species *A. ficulneus* is found in a vast geographic area stretching from Africa to Asia and Australia. It flourishes in tropical areas of low altitude with a long dry season such as desert regions of Sahelian Africa (Niger), Madagascar, East Africa, the Indian sub-continent, Indonesia, Malaysia and northern Australia (Van Borssum-Waalkes, 1966).

### Nutritional potential

K, Na, Mg and Ca are the principal elements in pods, which contain about 17% seeds; the presence of Fe, Zn, Mn and Ni also has been reported (Moyin-Jesu, 2007). Fresh pods are low in calories (20 per 100 g), practically no fat, high in fiber, and have several valuable nutrients, including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20% of folate (46 to 88 g) and about 5% of vitamin A (14 to 20 RAE) (NAP, 2006). Both pod skin (mesocarp) and seeds are excellent source of zinc (80 g/g) (Glew, 1997; Cook *et al.*, 2000). Okra seed is mainly composed of oligomeric catechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds), while the mesocarp is mainly composed of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins). Pods and seeds are rich in phenolic compounds with important biological properties like quercetin derivatives, catechin oligomers and hydroxycinnamic derivatives (Arapitsas, 2008). These properties, along with the high content of carbohydrates, proteins, glycol-protein, and other dietary elements enhance the importance of this foodstuff in the human diet (Manach *et al.*, 2005; Arapitsas, 2008). Dried okra sauce (pods mixed with other ingredients and regularly consumed in West Africa) does not provide any beta carotene (vitamin A) or retinol (Avallone *et al.*, 2008). However, fresh okra pods are the most important vegetable source of viscous fiber, an important dietary component to lower cholesterol (Kendall and Jenkins, 2004). Seven-days-old fresh okra pods have the highest concentration of nutrients (Agbo *et al.*, 2008).

## Seed as potential edible oil and flour source

Like soybean oil, okra seed oil is rich (60 to 70%) in unsaturated fatty acids (Crossly and Hilditech, 1951; Savello *et al.*, 1980; Rao, 1985). Seed protein is rich in tryptophan (94 mg/g N) and also contains adequate amounts of sulfur-containing amino acid (189 mg/g N) — a rare combination that makes okra seeds exceptionally useful in reducing human malnutrition (NAP, 2006). Okra seed protein with good protein efficiency ratio (PER) and net protein utilization (NPU) values is comparable to many cereals (except wheat) and its oil yield is comparable to most oil seed crops except oil palm and soybean (Rao, 1985). Moreover, okra seed oil has potential hypocholesterolaemic effect (Rao *et al.*, 1991). The potential for wide cultivation of okra for edible oil as well as for cake is very high (Rao, 1985). Okra seed flour could also be used to fortify cereal flour (Adelakun *et al.*, 2008). For example, supplementing maize *ogi* (maize dough) with okra meal increases protein, ash, oil and fiber content (Akingbala *et al.*, 2003). Okra seed flour has been used to supplement corn flour for a very long time in countries like Egypt to make better quality dough (Taha el-Katib, 1947).

## Non medicinal uses and Ethnopharmacology

Ambrette oil obtained from seeds possesses an odor similar to that of musk and its aromatic constituents have long been used in the perfume industry. Different grades of essential, or aromatic absolute, are marketed in Europe as high-grade perfumes (Singh *et al.* 1996). The seeds are valued for the volatile oil present in the seed coat. Seed analysis report 11.1% moisture, 31.5% crude fiber, 14.5% lipids, 13.4% starch, 2.3% protein, volatile oil (0.2-0.6%) and ca/ 5% resin (Srivastava 1995). Analysis of volatiles report myricetin-3-glucoside and a glycoside of cyanidin in flowers, an aromatic constituent in seeds, beta-sitosterol and its beta-D-glucoside, myricetin and its glucoside in leaves and petals and beta-sitosterol from dry fruit husk (Rastogi and Mehrotra 1991a,b).

In India, roots, leaves (rarely), and seeds of ambrette are considered valuable traditional medicines. The bitter, sweet, acrid, aromatic seeds are used as a tonic and are considered

Table 1 Ethnomedicinal uses of some members of the genus *Abelmoschus*.

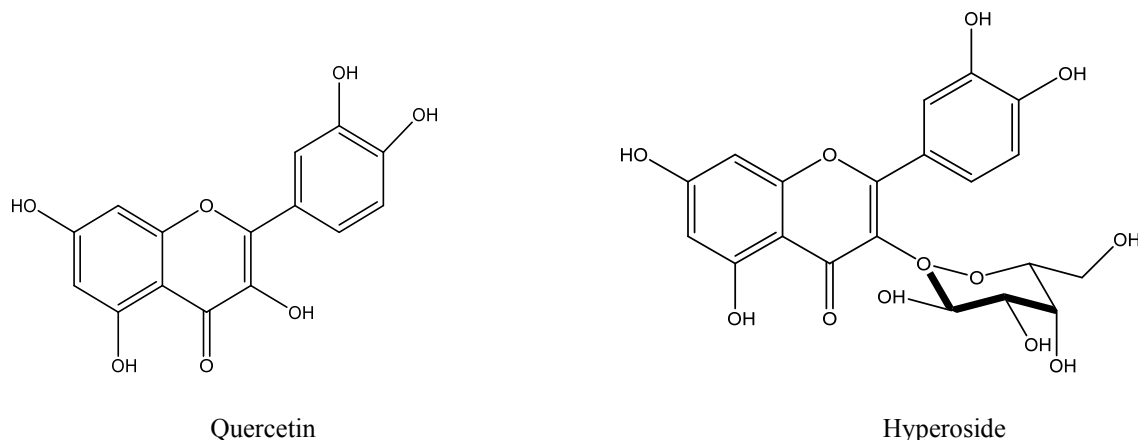
Plant	Ethnomedicinal use	Part used	Reference
<i>Abelmoschus ficulneus</i> (Linn.)	Scorpion bite Calcium deficiency	Fresh root	Jagtap <i>et al.</i> , 2006
<i>Abelmoschus manihot</i> (Linn.)	Sprain	Roots	Patil and Bhaskar, 2006
<i>Abelmoschus esculentus</i> (Linn.)	Emollient, demulscent Demulscent, anodyne, diuretic, anticatarrhal, dysentery, ardor urine, dysuria and gonorrhea Antioxidant effect Mucilages effect Anticomplementary and antidiabetic effect Antimicrobial effect Anticancer effect (antiproliferative and antiapoptotic actions) Antiulcerogenic	Pods Decoction of mature capsule  Seeds Mucilage  Mucilage Glycosylated compounds  Pods	Chatterjee and Pakrashi, 1995  Adelakun <i>et al.</i> , 2009; Adetuyi, 2008. Ameena <i>et al.</i> , 2010 Tomoda <i>et al.</i> , 1989  Lengsfeld <i>et al.</i> , 2004 Ilhan <i>et al.</i> , 2003 Shrikant <i>et al.</i> , 2011

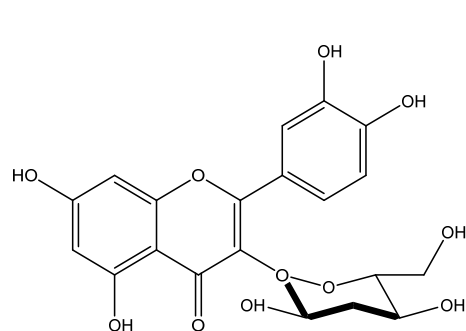
"cooling, aphrodisiac, ophthalmic, cardiogenic, digestive, stomachic, constipating, carminative, pectoral, diuretic, stimulant, antispasmodic, deodorant, and effective against "kapha" and "vata," intestinal complaints, stomatitis; and diseases of the heart, allays thirst and checks vomiting. According to *Unani* system of medicine seeds allay thirst, cure stomatitis, dyspepsia, urinary discharge, gonorrhea, leucoderma and itch. Roots and leaves are cures for gonorrhea (Agharkar 1991). Even use against venomous reptiles has been reported (Lindley 1985). A survey of the ethanobotanical literature shows that the roots, seeds, and aerial parts of *Abelmoschus manihot* are widely used in traditional medicine for the treatment of chronic bronchitis and, tooth-ache, emmenagogue, vulnerary; a paste of bark is used to treat cuts and wounds. In Nepal, the root juice is warmed then applied to treat sprains (Anonymous, 1976).

### Phytochemical studies

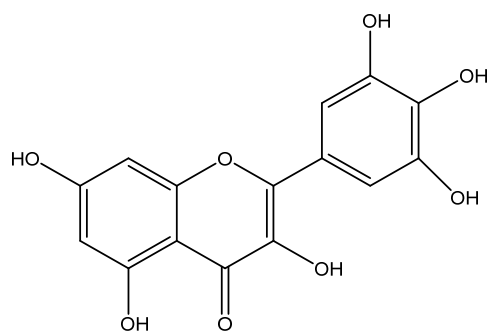
The flower of *A. manihot* was found to have anti inflammatory, antibacterial, and anticoagulant effects (Xiong *et al.*, 2006; Yao, 1994; Gu and Song, 1998). It has been used for treatment of chronic renal disease, mouth ulcers, and burns (Chen, 2001; Han and Situ, 1997; Zhang, 1997). Previous phytochemical studies indicated that flavonoids were the major constituents separated from the flower of *A. manihot* (Lai *et al.*, 2006; Wang *et al.*, 1981; Wang *et al.*, 2004 Lowey, 1976). The flavonoids isolated from the flower of *A. manihot* by the author include quercetin-3-O-robinobioside, hyperin, isoquercetin, hibifolin, myricetin, quercetin-3'-O-glucoside, and quercetin. Recent studies showed that flavonoids in *A. manihot* possess various biological activities, such as anti-inflammatory, antibacterial, antioxidant, and protective effects on the renal cellular membrane cells (Lee *et al.*, 2004; Waage and Hadin, 1984; Mahakunakorn *et al.*, 2004; Yokozawa *et al.*, 1999).

Jia *et al.*, 2011 reported isolating fourteen compounds and identified as 6-hydroxystigmasta-4-en-3-one (1), 6-hydroxy-stigmasta-4,22-dien-3-one (2), stigmasta-5-en-3-ol-7-one (3), stigmasta-5, 22-dien-3-ol-7-one (4), stigmast-5-en-3, 7-diol (5), stigmast-5, 22-dien-3, 7-diol (6), stigmast-4, 22-dien-3, 6-dione (7), stigmasta-4, 22-dien-3-one (8), ergosta-7, 22-dien-3-ol (9), cycloart-25-en-3,24-diol (10), lupeol (11), aurantiamide acetate (12), stigmasterol (13), hexadecanoic acid (14). Compounds 1-12 are obtained from the genus *Abelmoschus* plant for the first time and also from the Malvaceae for the first time. Structural formulae of some of the compounds isolated from members of the genus *Abelmoschus* are shown below.

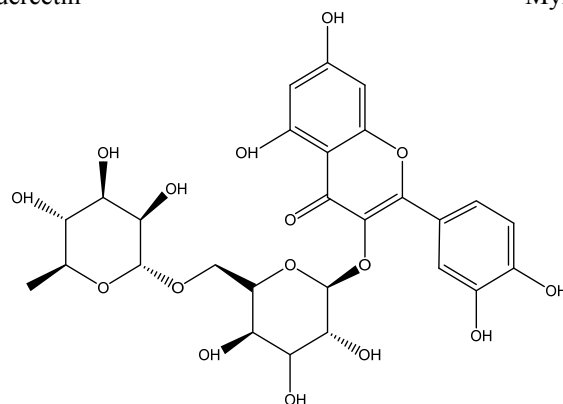




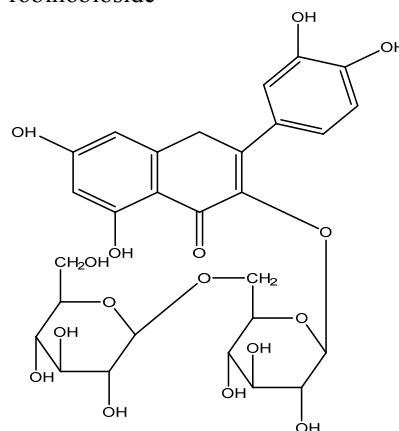
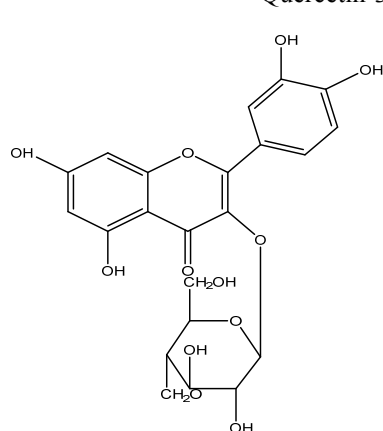
Isoquercetin



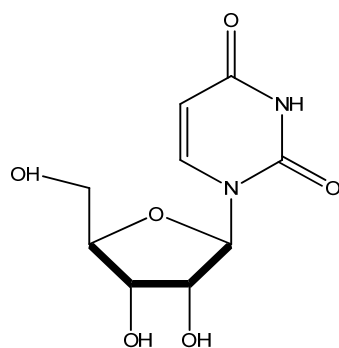
Myrecetin



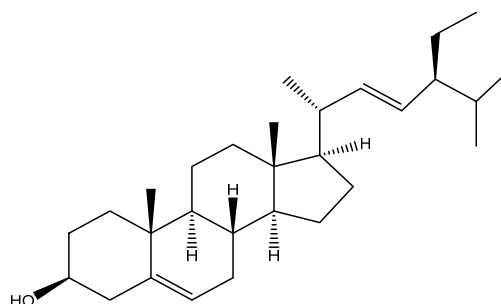
Quercetin-3-O-robinobioside



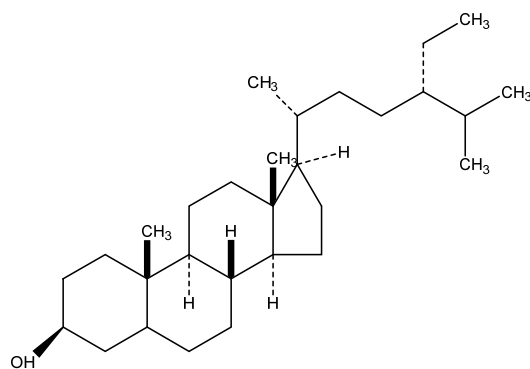
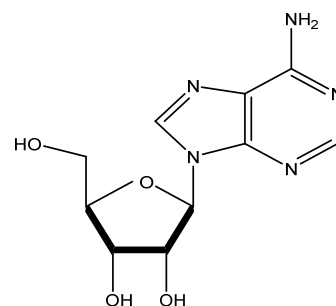
5,7,3',4'-tetrahydroxy-4''-O-methyl flavonol-3-O- $\beta$ -D-glucopyranoside and 5,7,3',4'-tetrahydroxy flavonol-3-O-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside



Uridine



Stigmasterol

 $\gamma$ -sitosterol

Adenosine

Table 2. Some compounds isolated from the genus *Abelmoschus*

Compound	Name	Plant source	Reference
1. Hyperoside/Hyperin	dihydroxyphenyl)-3-[(3 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> ,6 <i>R</i> )-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxy-4 <i>H</i> -chromene-4,5,7-triol	<i>Abelmoschus manihot</i> <i>Abelmoschus esculentus</i>	Lai <i>et al.</i> , 2009 Lowey, 1976 Wang <i>et al.</i> , 1981, 2004 Lin-lin <i>et al.</i> , 2007 Liao <i>et al.</i> , 2012 Lai <i>et al.</i> , 2009
2. Isoquercetin	2-(3,4-Dihydroxyphenyl)-5,7-dihydroxy-3-[(2 <i>S</i> ,3 <i>R</i> ,4 <i>S</i> ,5 <i>S</i> ,6 <i>R</i> )-3,4, 5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxychromen-4-one	<i>Abelmoschus manihot</i>	
3. Myricetin	3,5,7-Trihydroxy-2-(3,4,5-trihydroxyphenyl)- 4-chromenone	<i>Abelmoschus manihot</i>	Lai <i>et al.</i> , 2009 Lowey, 1976 Wang <i>et al.</i> , 1981, 2004
4. Hibifolin	Quercetin 3-beta-robinobioside; 3-[[6-O-(6-Deoxy-alpha-L-mannopyranosyl)-beta-D-galactopyranosyl]oxy]-2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-4 <i>H</i> -1-benzopyran-4-one	<i>Abelmoschus manihot</i>	Lai <i>et al.</i> , 2009 Lowey, 1976 Wang <i>et al.</i> , 1981, 2004
5. Quercetin 3-O-robinobioside	Quercetin 3-beta-robinobioside; 3-[[6-O-(6-Deoxy-alpha-L-mannopyranosyl)-beta-D-galactopyranosyl]oxy]-2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-4 <i>H</i> -1-benzopyran-4-one	<i>Abelmoschus manihot</i>	Lai <i>et al.</i> , 2009 Lowey, 1976 Wang <i>et al.</i> , 1981, 2004
6. Flavonoid glycoside	5,7,3',4'-tetrahydroxy-4''-O-methyl flavonol-3-O- $\beta$ -D-glucopyranoside	<i>Abelmoschus esculentus</i>	Liao <i>et al.</i> , 2012
7. Flavonoid glycoside	5,7,3',4'-tetrahydroxy flavonol -3-O- $[\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside	<i>Abelmoschus esculentus</i>	Liao <i>et al.</i> , 2012
8. Coumarin scopoletin	7-hydroxy-6-methoxychromen-2-one	<i>Abelmoschus esculentus</i>	Lu <i>et al.</i> , 2011 Bandyukova and Ligai, 1987
9. Uridine	1-[(3 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> )-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]pyrimidine-2,4-dione	<i>Abelmoschus moschastus</i> <i>Abelmoschus esculentus</i>	Li <i>et al.</i> , 2012
10. Stigmasterol	(3 <i>S</i> ,8 <i>S</i> ,9 <i>S</i> ,10 <i>R</i> ,13 <i>R</i> ,14 <i>S</i> ,17 <i>R</i> )-17-[( <i>E</i> ,2 <i>R</i> ,5 <i>S</i> )-5-ethyl-6-methylhept-3-en-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1 <i>H</i> -cyclopenta[ <i>a</i> ]phenanthren-3-ol	<i>Abelmoschus manihot</i>	Jain <i>et al.</i> , 2009



11. Gamma sitosterol	17-(5-Ethyl-6-methylheptan-2-yl)-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol	<i>Abelmoschus manihot</i>	Xian <i>et al.</i> , 2009
12. Adenosine	(2 <i>R</i> ,3 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> )-2-(6-amino-9 <i>H</i> -purin-9-yl)-5-(hydroxymethyl)oxolane-3,4-diol	<i>Abelmoschus manihot</i>	Lai <i>et al.</i> , 2007

## Pharmacological studies

### Analgesic effects

A study by Jain *et al.*, (2011) evaluated the analgesic activity of the crude dried petroleum ether and methanol extracts of *Abelmoschus manihot* using the hot plate and tail immersion tests. The results obtained indicate that the extracts possessed significant analgesic activity, which was found to be dose-dependent. A significant inhibition in pain threshold in hot-plate test was also exhibited; however in flick test, highest analgesic activity was observed only with 400 mg/kg dose as compared with the standard drug. The flowers were also reported to be used in the treatment of tooth ache (Lin-Lin *et al.*, 2007)

### Anti inflammatory effects

Jain *et al.* (2009) examined the anti inflammatory activity of the petroleum ether and methanol extracts of the leaves of the *Abelmoschus manihot*. The anti-inflammatory activity of the various extracts was studied based on their effects on carrageenan induced paw edema in rats (Jain and Bari, 2009). The petroleum ether and methanol extracts of leaves exhibited significant anti-inflammatory activities in a dose-dependent manner. The maximum anti-inflammatory activities were produced by the petroleum ether and methanol extracts at a dose of 100 200 400 mg/kg body weight (Jain and Bari, 2010).

### Larvicidal effects

In a study conducted to determine the larvicidal activities of *Abelmoschus*, Dua *et al.* (2006) reported the larvicidal activity of the roots of *Hibiscus abelmoschus* which was evaluated using the larvae of mosquitoes in the genera *Anopheles* and *Culex*. The mean median lethal concentrations of the aqueous extract of the roots of *H. abelmoschus* against the larvae of *Anopheles culicifacies*, *Anopheles stephensi*, and *Culex quinquefasciatus* were 52.3, 52.6, and 43.8 ppm, respectively (Winter *et al.*, 1962).

### Antiviral effects

In an investigation to evaluate the antiviral effects of *Abelmoschus*, Lin-lin WU *et al.* (2007) reported the antihepatitis B virus (HBV) effect of hyperoside extracted from *Abelmoschus manihot* (L) medik. The human hepatoma Hep G2.2.15 cell culture system and duck hepatitis B virus (DHBV) infection model were used as *in vivo* and *in vitro* models to evaluate the anti-HBV effects. The results showed that the 50 % toxic concentration of hyperoside was 0.115 g/L. At the maximum nontoxic concentrations, the inhibition rates of hyperoside on HBeAg and HBsAg in 2.2.15 cells were 86.41 % and 82.27 % on day 8, respectively. The inhibition of the peak of viraemia was maximum at the dose of 0.10 g/(kg·d) (Virenda *et al.*,

2006). The ethanol extract of flowers of *Abelmoschus manihot* was screened for antiviral activity and it was observed that the hyperoside has significant anti HBV activity (Lin-Lin *et al.*, 2007).

### ***Effect on nervous system***

Cheng *et al.* (2006) examined the modulatory effect of total flavone of *Abelmoschus manihot* L. Medic (TFA) on NMDA-activated current (*INMDA*) in cultured rat hippocampal neurons using the whole-cell patch-clamp technique. TFA rapidly and reversibly inhibited the *INMDA* in a concentration-dependent manner. Furthermore, TFA non-competitively inhibited the *INMDA* by enhancement of the NMDA receptor desensitization. In addition, intracellular application of TFA did not alter the TFA inhibition of *INMDA*. These results suggest that the inhibition of the NMDA receptor response by TFA could be one of the mechanisms controlling for TFA-mediated neuroprotective actions (Liu *et al.*, 2009).

In another study, Wen and Chen (2007) investigated the effect of pharmacological preconditioning of total flavones of *Abelmoschus manihot* (TFA) on a cerebral ischemic reperfusion injury in rats. The results obtained showed that there was an increase in serum LDH activity and the MDA level after ischemia/reperfusion but these changes were inhibited in rats pretreated with TFA (20, 40, 80, 160 mg/kg), indicating a delayed protective effect of TFA preconditioning on cerebral ischemic reperfusion injury (Jain and Bari, 2010).

Liu *et al.* (2009) investigated the protective effect of TFA against post stroke depression (PSD) injury in mice and its mechanism of action. A mouse model of PSD was induced by middle cerebral artery occlusion (MACO), then 30 min/reperfusion, followed by isolation feeding and chronic unpredictable mild stress for 2 weeks. Treatment with TFA (160, 80, and 40 mg/kg) significantly improved the escape-directed behavioral impairment induced by PSD; markedly reduced MDA levels, and increased the activity of SOD. TFA administration also attenuated PSD induced neuronal death/loss. TFA had a protective effect against PSD injury in mice (Wen and Chen, 2007). Guo *et al.*, 2011 in order to further explore the activity of *Abelmoschus manihot* on the central nervous system, investigated the anticonvulsant and antidepressant-like effects of *Abelmoschus manihot* ethanol extract (AMEE) as well as its potential active components. It was found that AMEE could protect mice against PTZ-induced clonic convulsions and mortality.

### ***Protective effects on osteoporosis***

Puel *et al.* (2005) investigated the ability of *Abelmoschus manihot* to prevent bone loss in ovariectomised rats. Osteopenia was prevented by administration of the highest dose of *Abelmoschus manihot* leaves extract. The lowest dose did not produce any significant effect allowing the authors to conclude that at a dose of 15 % in the diet bone-sparing effects were produced (Cheng *et al.*, 2006).

### ***Wound healing effects***

Jain *et al.* (2009) reported the wound healing activity of the petroleum ether and methanol extracts of *Abelmoschus manihot*. The ointment of the petroleum ether and methanol

woody stem extracts of *Abelmoschus manihot* was prepared using a simple ointment base. The results of their use showed that the ointment containing both the extracts of the woody stems of *Abelmoschus manihot* had significant wound healing activity compared with controls and the methanol extracts was more potent compared with the ointment containing petroleum ether extracts, probably because they may contain more active constituents (Puel *et al.*, 2005).

### **Antidiabetic activity**

In a study, Sabitha *et al.*, (2011) demonstrated the antidiabetic activities of *Abelmoschus esculentus* peel and seed powder (AEPP and AESP respectively). The author showed that administration of AEPP and AESP at 100 and 200 mg/kg dose in diabetic rats showed significant reduction in blood glucose level and increase in body weight than diabetic control rats. A significant increased level of Hb, TP, and decreased level of HbA1c, SGPT were observed after the treatment of both doses of AEPP and AESP. Also, elevated lipid profile levels returned to near normal in diabetic rats after the administration of AEPP and AESP, 100 and 200 mg/kg dose, compared to diabetic control rats. In a similar study, Saha *et al.*, 2011 observed that the aqueous extract of powdered *Abelmoschus esculentus* had maximum effect when Glibenclamide was used as a standard.

### **Effects on the GIT**

Shrikant *et al.*, (2011) studied the effects of the mucilage of *A. esculentus* at dose of 1g/kg and observed a significant inhibition of the ulcer induced by indomethacin. Pretreatment with the test extract significantly increased the amount of gastric mucus content in ethanol-ulcerated rats. Cyto-protection may be because of formation of a protective layer with increase in mucous secretion from the superficial epithelial cells.

### **Antioxidant and anticancer and antimicrobial activities**

Gul *et al.*, 2011 in a study shows that the antioxidant activities of *A. moschatus* as determined by the total phenol, flavonoids, total antioxidant and FRAP methods were higher in leaf than that of the seed extracts. On the other hand, the aqueous overnight seed extract (AMS-I) has shown significant radical scavenging activity as in 1, 1-Diphenyl-2-picrylhydrazyl (DPPH), hydrogen peroxide, hydroxyl radical, superoxide and lipid peroxidation as compared to other seed and leaf extracts. The AMS-I and AML-IV have shown activity against six and seven microorganisms respectively. Simultaneously, AMS-IV and AML-IV have demonstrated potential antiproliferative activity against two human cell lines - Colorectal adenocarcinoma (COLO-205) and retinoblastoma (Y79). In a similar study, Vayssade *et al.*, 2010 suggested that okra RG-I induces apoptosis in melanoma cells by interacting with Gal-3 thereby preventing cancer cell proliferation.

Maheshwari and Kumar (2009) examined the antimicrobial activities of the hexane, ethyl acetate, methanol and aqueous extracts prepared from the leaves of *Abelmoschus moschatus* against a number of pathogens by using disc diffusion assay method. Clear zones of inhibition were reported for *Staphylococcus aureus*, *Bacillus megaterium*, *Shigella flexneri*, *Proteus mirabilis*, *Proteus vulgaris* and *Cornebacterium diphtheriae*.

### **Hepatoprotective activity**

In a study by Alqasoumi, 2012, an attempt was made to validate the claimed uses of 'Okra' *Abelmoschus esculentus* in liver diseases. The preventive action of ethanolic extract of okra (EEO) against liver injury was evaluated in rodents using carbon tetrachloride (CCl<sub>4</sub>) induced hepatotoxicity model. EEO, at 250 and 500mg/kg body weight, exerted significant dose-dependent hepatoprotection by decreasing the CCl<sub>4</sub>-induced elevation of serum ALT, AST, ALP, GGT, cholesterol, triglycerides and malondialdehyde (MDA) non-protein sulphhydryls (NP-SH) and total protein (TP) levels in the liver tissue. A significant reduction was also observed in pentobarbital-induced sleeping time in mice. The hepatoprotective and antioxidant activities of the extract are being comparable to standard silymarin. These findings were supported by histological assessment of the liver biopsy.

### **Immunomodulatory effects**

In an *in vitro* study, Sheu and Lai, (2012) analyzed the composition of okra (*Abelmoschus esculentus* L.) extract and investigated the effect of *A. esculentus* L. polysaccharides (AE-PS) on the maturation and function of dendritic cells (DCs) derived from rat bone marrow hematopoietic cells (BMHCs). BMHC-derived immature DCs (BMHC-imDCs) were extracted from rats and treated with AE-PS. The hydrolyzed okra extract contained 0.6%  $\beta$ -1, 3-d-glucan. AE-PS induced the presence of polymorphic nuclei and elongated protrusion in the BMHC-imDCs, indicating DC activation. Treatment with 100  $\mu$ g/mL of AE-PS increased the MHC class II and CD80/86 expression levels by 41% and 42%, respectively. Treated cells had reduced endocytosis activity. The secretion of IL-12 and IFN- $\gamma$  increased significantly by 120% and 75%, respectively, when treated with 100  $\mu$ g/mL of AE-PS. Moreover, IL-10 production was reduced by 66%. In conclusion, AE-PS exhibits stimulatory effects on rat dendritic cells and promotes the secretion of T H1 cytokines.

### **Conclusion**

The genus *Abelmoschus* has been reported to used for several ethnomedicinal practices and have also demonstrated diverse pharmacological activities and posses several phytochemical and nutritional properties as well as having no adverse effect on living cells. Their pods, seeds and leaves are reported to be used as food, in pharmaceutical industries and as traditional remedies all over the world. The reported isolated compounds from the genus *Abelmoschus* have a primarane skeleton which could be responsible for the similar biological activity demonstrated by their respective extracts. Therefore, apart from the physical features used to classify the *Abelmoschus species*, taxonomists could also agree from the view point that plants could be classified on the basis of their chemical composition and biological activities.

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## Conflict of interest

There is no conflict of interest whatsoever associated with this paper.

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