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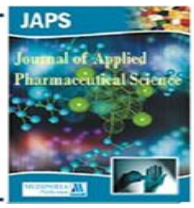

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Musa paradisiaca L. and *Musa sapientum* L. : A Phytochemical and Pharmacological Review

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ABSTRACT

Musa paradisiaca L. and *Musa sapientum* L. (Musaceae) are mainly grown in the tropical and subtropical countries and are widely used for its nutritional values all over the world. The fruits as well as the other parts of the plant are used to treat different diseases in human in traditional medicine. This review presents the scientific information on the traditional uses, phytochemistry and pharmacology of these two species. Both *M. paradisiaca* and *M. sapientum* are traditionally used in diarrhoea, dysentery, intestinal lesions in ulcerative colitis, diabetes, sprue, uremia, nephritis, gout, hypertension and cardiac disease. This review reports the phytochemicals isolated and identified from fruit pulp, peel, seeds and flowers. A comprehensive assessment of the biological activities of different extracts is included and possible mechanisms and phytochemicals involved have been correlated.

Key words: *Musa paradisiaca, Musa sapientum,* Musaceae, Traditional medicine, Phytochemicals, Pharmacological activities.

INTRODUCTION

Medicinal plants are frequently used in traditional medicine to treat different diseases in different areas of the world (Palombo, 2005). This indigenous knowledge, passed down from generation to generation in various parts of the world, has significantly contributed to the development of different traditional systems of medicine (Jachak and Saklani, 2007) as well as helped in exploration of different medicinal plants to find the scientific basis of their traditional uses. This exploration of biologically active natural products have played an important role in finding new chemical entities (NCEs) for example, approximately 28% of NCEs between 1981 and 2002 were natural products or natural product-derived (Newman et al., 2003). This review focuses on two common species of banana widely used as food and vegetable. This review presents the scientific information on uses, isolated chemicals and pharmacological studies to validate the traditional uses of *M. paradisiaca* and *M. sapientum* in different types of diseases.

Banana is a familiar tropical fruit. From its native Southwestern Pacific home, the banana plant spread to India by about 600 BC and later on it spread all over the tropical world. It is possibly the world's oldest cultivated crop. It even spread into the Islands of the Pacific and to the West Coast of Africa as early as 200-300 BC (Rahman and Kabir, 2003).

Musa paradisiaca is a herbaceous plant (up to 9 m long) with a robust treelike pseudo-stem, a crown of large elongated oval deep-green leaves (up to 365 cm in length and 61 cm in width), with a prominent midrib (Figure 1), each plant produces a single inflorescence like drooping spike, and large bracts opening in succession, ovate, 15-20 cm long, concave, dark red in color and somewhat fleshy. Fruits are oblong, fleshy, 5-7cm long in wild form and longer in the cultivated varieties. *Musa sapientum* is a treelike perennial herb that grows 5 - 9 m in height, with

tuberous rhizome, hard, long pseudostem (Figure 1). The inflorescence is big with a reddish brown bract and is eaten as vegetables. The ripe fruits are sweet, juicy and full of seeds and the peel is thicker than other banana.

(a)

(b)

Fig 1: Plants with fruits of (a) *Musa paradisiaca* and (b) *Musa sapientum.*

Taxonomical classification

Kingdom	: *Plantae*
Division	: *Magnoliophyta*
Class	: *Liliopsida*
Order	: *Zingiberales*
Family	: *Musaceae*
Genus	: *Musa*
Species	: *Musa paradisiaca, Musa sapientum*

Cultivation and Distribution

In different countries about 300 varieties of bananas are grown, of which a vast majority have been growing in Asian, Indo-Malaysian and Australian tropics and are now widely found throughout the tropical and subtropical countries. India, Philippines, China, Ecuador, Brazil, Indonesia, Mexico, Costa Rica, Colombia, Thailand are the top banana producing countries. It is extensively grown and cultivated as a fruit plant all over Bangladesh. The banana grows almost everywhere in the country throughout the year. The principal banana growing areas however, are Rangamati, Barisal, Rangpur, Dinajpur, Noakhali, Faridpur and Khulna (Rahman and Kabir, 2003).

Traditional Uses

The fruit of *M. paradisiaca* and *M. sapientum* is traditionally used in diarrhoea (unripe), dysentery, intestinal lesions in ulcerative colitis, diabetes (unripe), in sprue, uremia, nephritis, gout, hypertension, cardiac disease (Ghani, 2003; Khare, 2007). *M. spaientum* is also used in the treatment of excess menstruation with *Canna indica* L. var. *speciosa* (Partha, 2007). Banana leaves (ashes) are used in eczema (Okoli, 2007), as cool dressings for blister and burns (Ghani, 2003). Flowers are used in dysentery and menorrhagia. Stem juice of fruited plant is used for treating diarrhoea, dysentery, cholera, otalgia, haemoptysis and flower is used in dysentery, diabetes and menorrhagia (Ghani, 2003). The root is used as anthelmintic (Khare, 2007), blood disorders, venereal diseases (Ghani, 2003). The plant is also used in inflammation, pain and snakebite (Coe and Anderson, 1999).

Phytochemicals

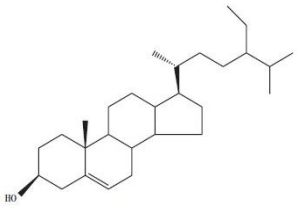
Carbohydrates have been isolated from *M. sapientum* (Anhwange, 2008). Catecholamines such as norepinephrine, serotonin, dopamine (Waalkes et al., 1958; Vettorazz, 1974), tryptophan, indole compounds (Shanmugavelu and Rangaswami, 1962), pectin have been found in the pulp. Several flavonoids and related compounds (Leucocyanidin, quercetin and its 3-O-galactoside, 3-O-glucoside, and 3-O-rhamnosyl glucoside) were isolated from the unripe pulp of plantain (Lewis et al., 1999; Lewis and Shaw, 2001; Ragasa et al., 2007). Serotonin, nor-epinephrine, tryptophan, indole compounds, tannin, starch, iron, crystallisable and non-crystallisable sugars, vitamin C, B-vitamins, albuminoids, fats, mineral salts have been found in the fruit pulp of *M. paradisiaca* and *M. sapientum* (Ghani, 2003).

Acyl steryl glycosides such as sitoindoside-I, sitoindoside-II, sitoindoside-III, sitoindoside-IV and steryl glycosides such as sitosterol gentiobioside, sitosterol *myo*-inosityl-β-D-glucoside have been isolated from fruits of *M. paradisiaca* (Ghoshal, 1985). Jang et al. (2002) isolated a bicyclic diarylheptanoid,*rel*-(3*S*,4a*R*,10b*R*)-8-hydroxy-3-(4-hydroxyphenyl) -9-methoxy-4a,5,6,10b-tetrahydro-3*H*-naphtho[2,1-*b*]pyran, and 1,2-dihydro-1,2,3-trihydroxy-9-(4-methoxyphenyl)phenalene, hydroxyanigorufone, 2-(4-hydroxyphenyl)naphthalic anhydride, 1,7-bis(4-hydroxyphenyl)hepta-4(*E*),6(*E*)-dien-3-one.

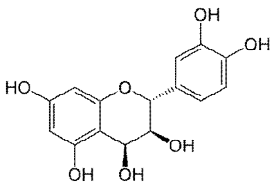
Ragasa et al. (2007) reported the isolation of several triterpenes such as cyclomusalenol, cyclomusalenone, 24-methylenecycloartanol, stigmast-7-methylenecycloartanol, stigmast -7-en-3-ol, lanosterol and β-amyrin. An antihypertensive principle, 7, 8-dihydroxy-3-methylisochroman-4-one, was isolated from the fruit peel of *M. sapientum* (Qian et al., 2007). Cycloartane triterpenes such as 3-epicycloeucalenol, 3-epicyclomusalenol, 24-methylenepollinastanone, 28-norcyclomusalenone, 24-oxo-29-norcycloartanone have been isolated from the fruit peel of *M. sapientum* (Akihisa et al., 1998).

Cellulose, hemicelluloses, arginine, aspartic acid, glutamic acid, leucine, valine, phenylalanine and threonine have been isolated from pulp and peel of *M. paradisiaca* (Ketiku, 1973; Emaga et al., 2007). Hemiterpenoid glucoside (1,1-dimethylallyl

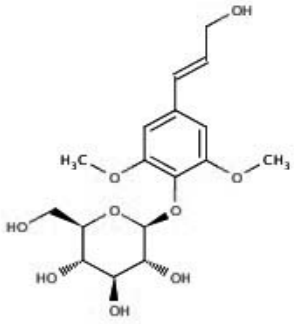
alcohol), syringin, (**6S**, 9R)-roseoside, benzyl alcohol glucoside, (24R)-4α,l4 α,24-trimethyl-Sacholesta-8,25(27)-dien-3β-o1 have been isolated from flower of *M. paradisiaca* (Duita et al., 1983; Martin et al., 2000). Structures of some important isolated chemicals have been included in Figure 2.



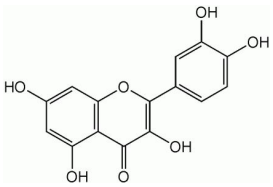
β-Sitosterol



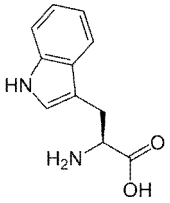
Leucocyanidin



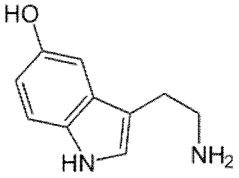
Syringin



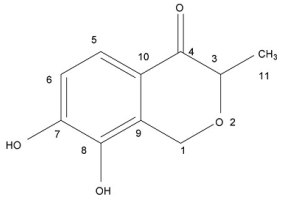
Quercetin



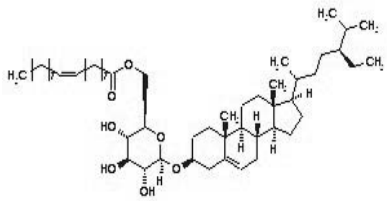
L-tryptophan



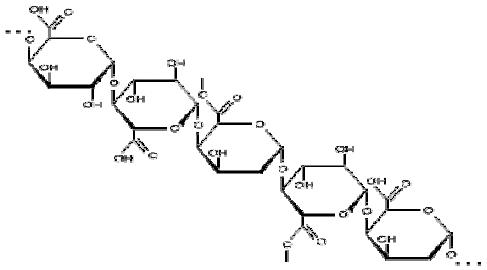
5-Hydroxytryptamine



7, 8-dihydroxy-3-methyl isochroman-4-one



Sitoindoside-II



Pectin

Fig 2: Structures of some phytochemicals isolated from *Musa paradisiaca* and *Musa sapientum.*

Pharmacological activities

Antidiarrhoeal activity

The antidiarrhoeal activity of banana in rats was observed as early as in 1930s. This effect in the intestinal diseases was attributed to the pectin content of banana. Later banana diet was reported to be effective and advantageous in bacillary dysentery in a proctoscopic study on 127 patients of age nine month to forty eight years (Block, 1941). Banana flakes has also been tested and found effective in the treatment for diarrhoea in critically ill patients receiving enteral feedings (Emery et al., 1997). The antidiarrhoeal activity of green banana diet was found very effective in children with diarrhoea (Rabbani et al., 1999, 2001).

Antiulcerative activity

Banana is used in the herbal medicine to treat peptic ulcer disease. The use of *M. sapientum* in peptic ulcer as a component of herbal medicine has been evaluated and found effective (Goel and Sairam, 2002). Dunjić et al. (1993) reported that pectin and phosphatidylcholine in green banana strengthens the mucous-phospholipid layer that protects the gastric mucosa. They also reported that the gastric mucosa protective activity of the banana is due to multiple active components. Lewis et al. (1999) reported that a natural flavonoid from the unripe banana (*M. sapientum* var. *paradisiaca*) pulp, leucocyanidin, protects the gastric mucosa from erosions. Leucocyanidin and the synthetic analogues, hydroxyethylated leucocyanidin and tetraallyl leucocyanidin were found to protect the gastric mucosa in aspirin-induced erosions in rat by increasing gastric mucus thickness (Lewis and Shaw, 2001). Goel et al. (1986) reported that banana pulp powder (*M. sapientum* var. *paradisiaca*) showed significant antiulcerogenic activity in aspirin-, indomethacin-, phenylbutazone-, prednisolone-induced gastric ulcers and cysteamine- and histamine-induced duodenal ulcers in rats and guinea-pigs, respectively. The authors attributed the effect to increased mucosal thickness and increased [^{3}H] thymidine incorporation into mucosal DNA that results in mucosal cellular proliferation and healing. Mukhopadhyaya et al. (1987) also found the same effects like Goel et al. (1986) in rat after orally administering banana pulp powder as aqueous suspension at 0.5 g/kg twice daily dose for 3 days. They also reported a significant decrease in gastric juice DNA content after the treatment. Pannangpetch et al. (2001) reported that the antiulcerative effect of banana may vary depending on different varieties of banana. They showed that the ethanolic extract of both *M. sapientum* and *M. paradisiaca* have significant gastroprotective effect but only *M. paradisiaca* promotes ulcer healing by a similar mechanism like prostaglandins. Jain et al. (2007) also reported acid neutralizing capacity of *M. sapientum* fruit peel ash in rats.

Antimicrobial activity

Aqueous extract of unripe fruit peels and leaves of *M. paradisiaca* var. *sapientum* has been reported to show antimicrobial activity against *Staphylococcus* and *Pseudomonas* species in dehydrogenase assay. The IC_{50} of the aqueous fruit peel extract were 143.5 and 183.1 µg/ml against *Staphylococcus* and *Pseudomonas* species respectively and in case of leaf extract

were 401.2 and 594.6 µg/ml respectively (Alisi et al., 2008). In this assay the fruit peel extract showed better activity against both the bacteria than leaf extract while the peel extract was more active against *Staphylococcus* (Gram-positive) than *Pseudomonas* species (Gram-negative). However, the alcoholic extract of stem of *M. paradisiaca* showed no activity against *Staphylococcus aureus, Salmonella paratyphi, Shigella dysenteriae, Escherichia coli, Bacillus subtilis, Candida albicans* (Ahmad and Beg, 2001).

It has been reported that both ethanolic and aqueous extract of unripe *M. sapientum* fruit showed good activity against *S. aureus* ATCC 25921, *S. aureus*, *Salmonella paratyphi*, *Shigella flexnerii*, *E. coli* ATCC 25922, *E. coli*, *Klebsiella pneumoniae*, *B. subtilis* and *Pseudomonas aeruginosa*. The minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) of unripe banana ranged 2-512 mg/ml and 32-512 mg/ml respectively considering both the solvents (Fagbemi et al., 2009). Though both ethanolic and water extracts showed significant activity against the organisms, the activity of ethanolic extract was stronger indicating that ethanol can dissolve the active phytochemicals than water. The aqueous extract of banana puree has also reported to have bacteriostatic activity against *B. cereus, B. coagulans, B. stearothermophilus, Clostridium sporogenes* (Richter and Vore, 1989).

Hypoglycemic activity

The green fruit of *M. paradisiaca* has been reported to have hypoglycemic effect due to stimulation of insulin production and glucose utilization (Ojewole and Adewunmi, 2003). Its high potassium (K) and sodium (Na) content has been correlated with the glycemic effect (Rai et al., 2009). Fibers from *M. paradisiaca* fruit increased glycogenesis in the liver and lowered fasting blood glucose (Usha et al., 1989). Antihyperglycemic effect of the hydromethanolic extract of *M. paradisiaca* root has been found significant (Mallick et al., 2006; Mallick et al., 2007). *Musa sapientum* showed antihyperglycemic effect in hyperglycemic rabbit (Alarcon-Aguilara et al., 1998). The chloroform extract of flowers of *M. sapientum* showed blood glucose and glycosylated haemoglobin reduction and total hemoglobin increase after oral administration in rats (Pari and Maheshwari, 1999). It also controls lipid peroxidation in diabetes (Pari and Maheshwari, 2000). However, *M. paradisiaca* stem juice showed hyperglycemic activity (Singh et al., 2007). Isolated pectin from the juice of the inflorescence stalk of *M. sapientum* increases the glycogen synthesis, decreases glycogenolysis and gluconeogenesis (Gomathy et al., 1990).

Hypocholesterolaemic activity

Hemicellulose and other neutral detergent fibers (NDF) from the unripe *M. paradisiaca* fruit showed low absorption of glucose and cholesterol and low serum and tissue levels of cholesterol and triglycerides (Usha et al., 1984). Flavonoids isolated from unripe fruits showed hypolipidemic activity evidenced by decrease in cholesterol, triglycerides (TG), free fatty acids and phospholipids levels in serum, liver, kidney and brain of rats. The cholesterol lowering effect was attributed to a higher degradation rate of cholesterol than synthesis (Vijayakumar et al., 2009). Methanolic root extract of *M. paradisiaca* showed total cholesterol (TC), triglyceride (TG), LDLc and VLDLc lowering effect in diabetic rats (Mallick et al., 2006). The pectin content in the juice of the inflorescence stalk of *M. sapientum* has also been reported to possess cholesterol and triglyceride lowering activity in rats (Gomathy et al., 1989).

Antihypertensive activity

The antihypertensive effect of *M. paradisiaca* in albino rats was reported by Osim et al. (1990). Later Osim and Ibu (1991) reported that banana diet has a mean arterial blood pressure lowering as well as onset preventing effect in rats with elevated blood pressure induced by desoxycorticosterone acetate (DOCA) administration. Perfumi et al. (1994) reported that the antihypertensive effect of ripe banana pulp in deoxycorticosterone enantate-induced hypertensive rats which may be due to the high tryptophan and carbohydrate content of banana that increases serotonin levels and gives serotonin-mediated natriorexic effect. However, Orie (1997) reported that serotonin produced a contraction in place of relaxation in isolated rat aortic rings. The aqueous extract of the ripe *M. paradisiaca* fruit was found to give a concentration-dependent hypotensive effect in both noradrenaline- and potassium chloride-contracted aortic rings isolated from rat. The effect was due to the non-specific interference in calcium ion availability needed for the smooth muscle contraction that results in relaxation.

Effect in atherosclerosis

Saraswathi and Gnanam (1997) reported that *M. paradisiaca* inhibits cholesterol crystallization *in vitro* which may have an effect on atherosclerosis plaque and gallstones *in vivo*. Parmar and Kar (2007) tested the peel extract of *M. paradisiaca* in rats with diet-induced atherosclerosis. This study reports the protective role of the extract in atherosclerosis and thyroid dysfunction though it was not very effective like other plants tested. Yin et al. (2008) further studied the effect of banana in human and found that plasma oxidative stress was significantly reduced and the resistance to oxidative modification of LDL was enhanced only after a single banana meal. The effect may be due to the presence of dopamine, ascorbic acid and other antioxidants present in banana.

Antioxidant activity

Plasma oxidative stress is significantly reduced only after a single banana meal in healthy human due to the presence of dopamine, ascorbic acid and other antioxidants present in banana (Yin et al., 2008). Antioxidant activity was also reported with aqueous acetone extract of banana peel by β-carotene bleaching method, DPPH free radical scavenging and linoleic acid emulsion method. Glycosides and monosaccharide components are mainly responsible for the antioxidant activity (Mokbel and Hashinaga, 2005). Vijayakumar et al. (2008) reported the antioxidant activity of the extracted flavonoids from *M. paradisiaca* in rats. They

found that the flavonoids from banana stimulated the activities of superoxide dismutase (SOD) and catalase which might be responsible for the reduced level of peroxidation products such as malondialdehyde, hydroperoxides and conjugated dienes.

Diuretic activity

Ash of the peel of *M. sapientum* showed an increase in urine volume and K^+ as well as other electrolyte excretion than normal saline in a study in rats. Successive ethanolic extract also give this diuretic effect (Jain et al., 2007). Phytochemicals such as saponin, flavonoids and terpenoids are known to be responsible for this effect (Rizvi et al., 1980; Sood et al., 1985; Chodera et al., 1991).

Wound healing activity

Agarwal et al. (2009) reported the wound healing activity of both methanolic and aqueous extract of plantain banana (*M. sapientum* var. *paradisiaca*) in rats. Both extracts were found to increase hydroxyproline, hexuronic acid, hexosamine, superoxide dismutase as well the wound breaking strength and reduced glutathione level. They also decreased the wound area, scar area and lipid peroxidation. The effects were attributed to the antioxidant property of the plantain.

Anti-allergic activity

The water extract of pulp of ripe *M. sapientum* has been reported to have significant anti-allergic activity on antigen-induced degranulation in RBL-2H3 cells with an IC_{50} value of 13.5±2.4 (Tewtrakul et al., 2008).

Antimalarial activity

The decoction of the leaves of *M. paradisiaca* added to *Ocimum americanum* and *Ocimum gratissimum* is used as to treat malarial in Comores, Ngazidja. But *in vitro* study using *Plasmodium falciparum* chloroquine-resistant strain proves this plant ineffective in malaria (Kaou et al., 2008).

Effect on Muscle

The stem juice of plantain banana tree (*M. sapientum* var. *paradisiaca*) has been found to induce contraction in skeletal muscles by enhancing excitation-contraction coupling and transmembrane Ca^{2+} fluxes (Singh and Dryden, 1990). Later, Benitez et al. (1991) reported the trunks juice of *M. sapientum* var. *cavendishi* has muscle paralyzing effect in rat and attributed the effect to monopotassium oxalate present in the juice.

Anti-snake venom activity

Borges et al. (2005) reported the *in vitro* neutralizing capacity of *Bothrops jararacussu* and *Bothrops neuwiedi* snake venoms by the stem juice of *M. paradisiaca*. The phospholypase A_2 (PLA_2) and hemorrhagic activities induced by the venom was inhibited by the extract as it forms unspecific complex with the venom protein. However, the *in vivo* activity of the extract in mice was not significant to protect against the venom (Borges et al. 2005).

Mutagenecity

Andrade et al. (2008) reported the mutagenic effect of *M. paradisiaca* fruit peel extract in mice assessed by the single-cell gel electrophoresis (SCGE) and micronucleus assays. The experiments showed DNA damaging property in peripheral blood leukocytes for 1500 and 2000 mg/kg body weight.

Conclusion

This review presents some phytochemicals and detailed pharmacological information of *Musa paradisiaca* and *Musa sapientum*. The review of pharmacological studies suggests that the traditional uses of the plant in diarrhoea, dysentery, ulcer, diabetes, hypertension and cardiac diseases are scientifically valid. However, clinical studies in human are still not available that may provide evidence of efficacy of the plant in human. Besides, still there are options to investigate the unexplored potential of the plant based on its uses. Furthermore, bioactive constituent(s) needs to be isolated and should be considered for further *in vivo* studies to confirm the claims and to explore the potential of development of leads that may contribute in drug development.

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